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EDITED BY
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HOWARD C. WARREN, PRINCETON UNIVERSITY (*Review*)
S. W. FERNBERGER, UNIVERSITY OF PENNSYLVANIA (*J. Exper. Psychol.*)
W. S. HUNTER, CLARK UNIVERSITY (*Index*)
E. S. ROBINSON, YALE UNIVERSITY (*Bulletin*)

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No. I

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RAYMOND HOLDER WHEELER

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PREFACE

The University of Kansas Studies in Psychology, Number I, is the first of a series of investigations organized about the general problem of configurational response. The editor has assumed the attitude throughout of holding the author in each case responsible for what is said. If, in the author's opinion results justified a criticism or limitation or even denial of configurational principles, he was perfectly free to assert himself accordingly. On the other hand, if he so desired he interpreted his results in a configurational fashion.

All of the separate papers are condensations of what were originally much more elaborate studies. If for any reason the reader should desire a more elaborate statement of any point contained in the monograph, he may receive such a statement by writing to the editor. The investigations reported by Doctors S. Howard Bartley, Thomas D. Cutsforth, Margery G. Cutsforth, O. B. Baldwin, and Messrs. Roy L. Roberts and F. Theodore Perkins were carried out under the general direction of the editor. Investigations reported by Dr. Warren W. Wilcox and Dr. Donald F. Showalter were supervised by Dr. Beulah M. Morrison. The chapters by Dr. E. K. Patton and Mr. Robert L. Brigden were written with the joint supervision of Doctors R. H. Wheeler and Harry R. DeSilva. The investigation by Mr. Cree Warden was carried out under the direction of Dr. DeSilva. The study by Mr. Byron C. Sarvis was performed under the direction of Doctors R. H. Wheeler and Beulah M. Morrison.

The editor wishes to express his appreciation to Mr. F. Theodore Perkins, Mr. William Blair, and Miss Ruth Waters for their assistance in preparing the manuscript, and to the authors for their hearty co-operation.

THE EDITOR

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A STUDY OF CEREBRAL ACTION CURRENTS IN THE DOG UNDER SOUND STIMULATION[1]

by

F. THEODORE PERKINS

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I. INTRODUCTION

Studies intended to clarify our conceptions of brain functions and particularly the functions of the cerebral cortex have, for the most part, been made with the animals behaving under abnormal conditions. Results from an organism behaving under distinctly novel conditions, when a part of the brain is destroyed or the entire organism incapacitated, have generally proved fatal to a correct understanding of the normal animal. For this reason it is believed that many of our current conceptions of brain functions have proved to be incorrect.

The action current technique employed by Bartley and Newman (1) proves to be an important advance over the older methods of approach to the problem of cerebral activity. The

[1] This investigation was carried out with the assistance of Dr. S. Howard Bartley, who, at the same time, was working on a parallel problem with the same apparatus and animal subjects. The writer takes this opportunity to express his appreciation of Dr. Bartley's valuable co-operation.

action current method has the advantage of not destroying or incapacitating any portion of the cortex. Further, with improvements in operative technique, it reduces to a minimum abnormal changes in the condition of the animal. This investigation is concerned solely with cortical activity of the animal under auditory stimulation of varying degrees of intensity and pitch.

II. Historical

The earlier investigations of auditory brain functions were carried out either with faradic stimulation or by extirpation techniques. Ferrier (2) was the first investigator who attempted to localize a center for hearing. Working under atomistic assumptions, he pointed out that the auditory center was located in the superior temporal lobe in the ape and in the dog. By means of faradic stimulation of this region he produced movements of the ears, opening of the eyes, dilation of the pupils and movement of the head and eyes 'as if the animal were surprised by some unexpected sound.' When the superior temporal gyrus was cauterized, and the ear plugged on the same side, Ferrier found that the animal would not react to sound. Bilateral lesions caused deafness.

Several years later, Goltz (3) removed the entire cerebrum from a dog which lived over eighteen months under constant observation in the laboratory. When stimulated by very high or very loud tones the animal would 'prick up its ears' and turn its head. If the stimulus was very intense, it would even strike at its ear with the forepaw "as if it wished to stop its ear." From these observations, Goltz denied that the animal was 'totally deaf.'

Munk (4) reviewed Goltz's work and suggested that the animal was reacting to pain stimuli and not to the tone or even the noise. Experiments on dogs were also performed by Munk. Before he operated he observed how his animals responded to nine pipe-organ tones of an octave interval, considering the animal's ear, head, and body movements as criteria of hearing. If these movements no longer persisted after an operation on the cerebrum, he assumed that deafness had been produced. Munk

then extirpated various sections of the supposed auditory region in his trained dogs and compared the motor reactions that occurred before the operation and afterward. He concluded that the dog's center for hearing lay in the temporal lobe; that perception of the higher tones was conditioned by the function of the anterior portion of this center, while that of the deeper tones depended on the activity of the posterior region. Following Munk, Kalischer (5) observed that post-operative dogs, which failed to make the responses considered by Munk to be criteria of hearing, could still respond to sound.

Kalischer also reported a series of experiments designed to test the relation between the temporal cortex and tone perception. He used six different breeds of dogs which he trained to take food at the sound of a given tone, and to refrain from seizing it at the sound of any other. The food was either held in the experimenter's hand or laid on a table in front of the animal. The first tones employed were produced on an organ which consisted of nine pipes ranging from C1 to C7. Piano and harmonium tones were used in the last part of the experiment. During the first few days of experimentation the one tone only was sounded and the animal fed during the time the sound lasted. Later, other sounds were given in chance order with the 'correct' stimulus, but the animal received food only when the 'correct' sound occurred. When the dogs were making perfect reactions to the sound situation, Kalischer made tests to establish the validity of the sound discrimination. In certain of the animals the eyelids were sewed shut, which did not affect the performance, indicating that visual cues were not responsible for the "sound" discrimination. He then destroyed one cochlea in several of the trained dogs, which resulted in no disturbance of sound discrimination. He then destroyed both cochlea in some of the animals and as a result all discrimination ceased. Further, dogs with both cochlea destroyed before training, did not learn to discriminate.

Kalischer then operated on the auditory region that Munk outlined. The first operation was the extirpation of one temporal lobe in an animal whose cochlea had been destroyed on the

same side. In this case, when the operation involved the entire temporal lobe, total deafness might be expected if Munk's view was correct, or, if the posterior portion of the lobe were extirpated the animal should be deaf to deep sounds, or if the anterior portion were destroyed, it should be deaf to high sounds. However, Kalischer reports that the animal reacted to sounds as before the operation, whether the extirpation was partial or complete. There were noticeable disturbances in response to commands and in orientation, but not in sound discrimination. Before proceeding to the opposite temporal lobe, he allowed several weeks for the animal to recover, during which time he observed no change in the animal's sound discrimination.

When the second temporal lobe was removed from certain of the animals, the visual area was also injured. The operation included all the temporal lobe and extended somewhat beyond in a posterior direction. The extirpation was deep, in some cases cutting into the ventricle. Kalischer reports that part of the peripheral visual field in each eye was lost. The dogs no longer reacted to spoken commands, nor did they show, by pricking of the ears or by head movements, that they were sensitive to loud noises. Later the animals began to resume movements in response to loud noises and very loud commands, but did not learn to discriminate between them. These movements of the head and ears disappeared entirely after the destruction of the corpora quadrigemina. Responses to tones, however, were much less affected. The animals did not always respond correctly, but undoubtedly discriminated between the food tones and the incorrect tones. Kalischer reports that, from the second week on, the animals began to exhibit their old degree of accuracy. In fact, in many cases, their discrimination improved rather than diminished. He found, further, that animals which had not been trained and had both temporal lobes extirpated, could be taught to make the same discriminations, but required a longer time than the others.

Following Kalischer, Rothmann (6) repeated the former's experiments with slightly different results. He believed that Kalischer gave the dogs certain unconscious cues during the

testing, and for that reason, in his own experiment, remained beyond the animals' range of vision. He trained the dogs to respond to the same stimuli employed by Kalischer. Rothmann was particularly interested in the function of the corpora quadrigemina, the destruction of which, Kalischer had reported, did not destroy pitch discrimination. After training the animals to the tones, he also trained them to come for food at certain words. The animals were then subjected to extirpation of both posterior corpora quadrigemina. Rothmann noted that, after the operation, the animals reacted to sounds and noises, but could not discriminate between them, nor learn to thereafter. In other dogs, he extirpated both temporal lobes, which produced deafness both to tones and noises. If, however, the entire lobe was not removed, some trace of the reactions remained. One of the animals, with both temporal lobes removed, was trained to react only to the tone C–256 d.v., and also to spoken words. Extirpation of both internal geniculate bodies, which, according to Rothmann, are relay stations from the ear to the cortex, destroyed all discrimination, as well as the possibility of further training.

Swift (7) trained two dogs to discriminate between C1 and E2 sounded on trumpets. After perfection of discrimination was reached, he extirpated the left temporal lobe. The reactions to tones were undisturbed, and the training was resumed three days after the operation. Ten days later, the right temporal lobe was destroyed. This operation, Swift noted, rendered the animal almost totally blind, but discrimination between the tones was not disturbed. He concludes, therefore, that the center for pitch discrimination is *outside* the temporal lobe.

Johnson (8) criticizes these experiments, in which pitch discrimination was retained or relearned after the extirpation of the temporal lobes, on the ground that the experimenter was giving the animal cues as to the correct response. In light of Rothmann's procedure, this criticism would seem unfounded, as well as the fact that in general this group of experiments seem to be consistent with later studies on extirpation of the cerebral cortex (Lashley, 9). Johnson also disagrees with these earlier reports for the reason that in his own experiments on the intact dog, he

failed to obtain pitch discrimination of any kind. Evidence since the time of Johnson, presented particularly by the Russian school, seems to prove without a doubt that the normal dog can discriminate markedly well between tones of different pitch. Anrep (10) reviews the evidence from the conditioned reflex technique. Boormakin (11) showed that the dog possessed an upper limit of hearing between 80,000 and 100,000 vibrations per second. Nicholaiev found pitch discrimination in the dog between sounds of 30,000 and 27,750 vibrations, that is, of less than half a tone. Beliokav found a discrimination of one-fourth and one-eighth tone intervals (800, 812, 825 vibration sounds used as stimulation). Anrep conditioned dogs to discriminate an 850 vibration tone from a 722.5 vibration tone, less than a full tone difference. He also found that with weak tones, there was a longer latent period in the response. Tihomirov is cited by Pavlov (11) as having performed the only study on intensity discrimination. He used an organ pipe with an arrangement for damping the sound as desired. With an intensity very closely approximating the one used as the positive conditioned stimulus, differentiation could be made by the dog, with absolute accuracy, when a recess of 17 hours was introduced between the two stimuli. The experimenter himself was unable to detect a difference between the two sounds unless they followed each other immediately. These studies seem to demonstrate without a doubt the ability of the dog to make sound discriminations.

Other studies yield evidence concerning the amount of the cortex involved in pitch and general sound discrimination. Luciani (12) showed that the auditory function spreads more or less beyond the superior temporal region. He also recognized the fact that the auditory paths are, for the most part, crossed and that lesions of the surrounding areas cause psychical deafness; that lesions of the superior temporal gyrus cause cortical deafness; that unilateral lesions soon become compensated for, and that bilateral lesions result in more serious and permanent defects of hearing. According to von Monakow the cortex of the temporal lobe, especially the superior gyrus, is in direct connection with the medial geniculate body by means of the auditory radi-

ations. Papez (13) points out that to what extent the auditory temporal region co-operates with the angular and occipital region, is not known, *but that some contiguity and overlapping of 'structure' seems to be present.* Pavlov (11), however, concludes from his experiments that there is no evidence of important 'associations' between the sensory areas in the so-called association or silent regions of the brain.

The extirpation studies of Lashley (9) and others, demonstrate conclusively the fallacy of the localization of function theory. The studies just reviewed, although not specifically designed to demonstrate this fact in audition, show possibilities in this direction and bear out the facts which earlier investigators like Kalischer, Rothmann and Swift found in their attempt to locate the auditory function. The lack of specificity of function noted by these investigators harmonizes well with the views of mass action and equipotentiality outlined by Lashley. Moreover, Lashley found incidental evidence pertaining to the so-called auditory region. When this area was destroyed in the rat, there was no observed difference in the rate of learning or in the retention of the problem-situations, which Lashley used to test his animals. In fact, no specific area in the cortex was essential for the performance; rather, a certain mass of the entire cortex was required for the solving of the problems presented.

Other investigators have taken the pharmacological approach to the problem of cerebral function. Dusser de Barenne (14) found that strychnine was a convenient drug with which to stimulate the cortex because of its specific action and strength. He exposed the cortex and applied, with a cotton wad, 1 p.c. strychnine sulphate solution, colored with toluidin blue, to the area desired. The surface of the cortex was then wiped dry, the dye showing the area affected by the drug. The skin was then brought together over the skull, and the animal observed. This method showed that a wide variety of sensory responses could be elicited from a given portion of the cortex. He found, for example, that when the strychnine was applied to the motor area, the animal (cat) would shake its head violently, was sensitive to pain and touch on the forelegs; if the whiskers, face or ears were

lightly stroked, the animal at once reacted with violent defensive movements. In general, this work indicated that the so-called auditory region was involved in head sensitivity and head movements, in foreleg activity, and in general sensory disturbance involving all four legs and the rest of the body.

III. Related Studies

A survey of the literature shows that there is no previous study which is directly allied to the present research. There are, however, several investigators who have presented evidence which seems to have bearing on the present report. Buytendyk (15) stimulated the ear of the rabbit with the noise of a pistol shot and found a diphasic and monophasic electrical response in the auditory nerve, lasting about one-fiftieth of a second. As compared with the response of the motor nerve, this is very long, which he attributed to a discharge of more than a single volley of impulses. Adrian (16) reported that the maximum frequency in sensory nerves, under present methods, does not exceed 300 to 400 per second. He also showed the all-or-none character of the response of sensory fibres. Gasser and Erlanger (17) found the absolute refractory period of the sensory nerve to be .58 sigma, which would make a maximum frequency of 1724 impulses per second theoretically possible. Adrian, as it has already been noted, however, could obtain nowhere near this frequency. Adrian and Zotterman (18) produced evidence that intensity of the stimulus is represented by the frequency of the nerve-fibre response. These men have shown, in the case of a single sensory nerve-fibre, that the impulses are graded, as to frequency, according to the intensity of the stimulus.

Forbes, Miller and O'Connor (19) performed an experiment designed to record the sound stimulus from the mammalian medulla. As the auditory nerve is composed of thousands of fibres and these fibres branch extensively at their central connections in the medulla, the record was a composite picture of a multiple response (Forbes and Cattell, 20). The method was to connect the medulla oblongata or the brain stem of a decerebrate cat with a string galvanometer and to record galvanic excursions

evoked by various forms of acoustic stimuli in the vicinity of the cat's ear. The brain stem was transected at the level of the anterior colliculi and silver chloride electrodes applied to the dorsal surface of the medulla oblongata. Wicks of twine soaked in Ringer's solution made contact with the tissue. In most of the experiments the active lead was applied to the exposed surface of the medulla; the indifferent electrode was applied to the right posterior colliculi. The sound stimuli were a watchman's wooden rattle which had a duration of less than 25 sigma and could give a frequency of 70 per second, a number of tuning forks, and a siren which had an estimated range of 1 to 1,000. The results showed that with the watchman's rattle there appeared a fairly sharp excursion of the galvanometer, followed by a decline which was less rapid than the onset. This would suggest an almost synchronous volley of impulses entering the medulla, but not as synchronous as that evoked by an induction shock in the motor nerve. Varying the distance of the sound from the ear, and thus reducing the intensity, produced excursions of less and less amplitude as the sound receded from the animal. In both the medulla and the brain stem, there seemed to be a correspondence between frequency of excursions and the frequency of the rattle (70 per second). With the tuning forks, less satisfactory results were obtained, the record in most cases showing only an initial throw. In this case, there was no correlation between sound and frequency on the record. With the siren more satisfactory results were obtained. There seemed to be a general level of activity which did not at all correspond with the frequency of the siren for the high frequencies, but as the frequency decreased, there appeared a somewhat closer correspondence. The maximum physiological frequency, however, did not exceed 155 per second. The evidence from this study is rather meager at best, and the work met with numerous technical difficulties. It does show, however, that there are responses in the medulla and the brain stem to acoustic stimuli, *and that these are responses of the mass of tissue, not of the individual fibres or individual tracts.*

The electrical response of the auditory nerve has been investigated by Wever and Bray (21). They decerebrated cats and

exposed the auditory nerve. The active electrode, a small copper hook, was placed around the nerve, while the inactive electrode was located on some other portion of the body. The nerve currents taken from the auditory nerve were amplified by four stages of vacuum-tube amplification and transmitted to a telephone receiver. The amount of amplification varied from 320 times to 100,000 times. Sound stimulation consisted of spoken words, complex sounds, such as noises, and tones which ranged from 105 to 5,200 vibrations per second. The procedure was to apply the sound to the cat's ear in one room, with the observer listening in a telephone receiver in another room, noting the loudness, pitch, and quality of the sound which came through the receiver. Wever and Bray found a direct correspondence between the kind of sound stimulation and the sound which came out of the receiver. Spoken words were clearly understood and the person's voice was recognizable. Pitch was recognizable as high as 3,000 cycles. There also seemed to be a direct correlation between the intensity of the stimulus and the sound from the receiver.

Various checks were carried out during the experiments. When the electrode was placed on other tissue than that closely allied to the auditory function, the receiver sounds disappeared, demonstrating, according to Wever and Bray, that the results were not caused by mechanical vibration of the electrodes. When the animal died during the recording, there was a gradual decrease in the intensity of the response, and finally, cessation after about 15 to 20 minutes. Destruction of one cochlea decreased the intensity of the receiver sound, and destruction of both cochleas destroyed the response entirely. Transference of the electrode to regions of the medulla and brain stem did not destroy the response if one cochlea was intact. In certain animals the response could be obtained from the skin, muscle or bone near the ear, but not from parts distant from the ear. Responses could be obtained from all parts of the cerebellum, from cerebral tissue, both before and after decerebration, from temporal and parietal lobe, and from skin and muscle in the temporal region. In certain of the experiments it is curious that the responses were

obtained when *both* the electrodes were placed on wet cotton on the temporal bone.

These checks seem to demonstrate that Wever and Bray were not recording action currents of the auditory nerve as the cotton, bone and skin cases would indicate. To substantiate this point Adrian (22) repeated Wever and Bray's experiment. He found that he obtained the same results as far as transmission of the sound was concerned, but that this result was due to electrical variations accompanying the functioning of the cochlea rather than to action currents of the auditory nerve. Adrian found that his results were not modified by chilling the nerve with ice or by altering its conduction capacity by novocaine or the injection of acetic acid or by partial lesions of the nerve. If the electrodes were placed on the petrous bone, distant from the nerve, the conduction still occurred with an intensity which precluded the possibility of conduction, through the bone, of the slight differential found in nerve action currents. The abolition of the effects with the death of the animal or by cutting the nerve is ascribable, according to Adrian, to mechanical modifications of a circulatory nature in the arteries accompanying the nerve. Adrian's and Wever and Bray's experiments demonstrate that the cochlea exhibits a microphonic functioning and do not, seemingly, demonstrate action currents of the auditory nerve.[1]

The unsettled condition of data on the auditory function as outlined in this section, justifies additional experiments, with new, improved, and better controlled technique.

IV. Method

(1) Apparatus. The apparatus employed in this experiment is the same as that used by Bartley and Newman (1) and, therefore, has been described in detail elsewhere. A brief review of the apparatus will be given here, however, for the sake of continuity, and new features which did not exist at the time the earlier report was made will be described. In general the apparatus consisted

[1] Adrian, Bronk and Phillips (23) have recently found that the Wever-Bray effect may be due in some measure to nervous origin since a blocking occurs when novocaine is applied to the nerve.

of three parts: (1) the amplifying set and accessories; (2) the oscillograph and optical system; and (3) the camera.

The amplifying set consisted of five stages of vacuum-tube amplification. The first three stages were situated in the operating room which was lined on all sides, the roof and the floor, with metal sheeting (grounded), which was designed to reduce to a minimum any extraneous electrical field that might interfere with the recording. The lead passed from the points of a multiple switch on the operating table into the first three stages of the amplifier. In addition to the shielding of the room, the tubes of the amplifying set were protected by copper plates and the entire set encased in a box heavily padded with cotton batting. Direct current batteries eliminated the need for an alternating current in the operating room. General illumination of the room during the period of recording, also, was supplied by direct current from an ordinary 12-volt storage battery. The room was shielded, further, by a layer of celotex inside the layer of tin.

The leads passed out of the amplifier through the wall of the room across another room to the last two stages of amplification. Shielding was not of the importance here as in the first three stages because any electrical potential introduced at this end would not receive the amplification that an extraneous potential would receive if introduced into the first stages. These latter stages received their current through an alternating current transformer. The leads out of the last stage of amplification passed to the oscillograph element.

The Westinghouse oscillograph element was used as the galvanic instrument. The advantages of this instrument over the string galvanometer, phoneloscope or capillary electrometer have already been outlined, but are, essentially, the high frequency of vibration and the relative lack of friction, made possible by the practically instantaneous damping of the torque exerted on the string. The light source was provided by an Eastman Kodascope lamp which passed through the set of prisms provided in the standard Westinghouse optical system. This system and the oscillograph element were arranged in a box designed after the multiple-element Westinghouse oscillograph instrument. The

optical box made possible a careful focusing of the light-beam on the mirror of the oscillograph element at the other end of the box. This light-beam was reflected by the mirror and passed out of the box through a large cylindrical lens which is part of the optical system mentioned above. This light-beam then passed into the camera box.

The camera box was designed especially for this experiment. It was constructed of galvanized sheet iron and fitted into grooves on the outer part of the optical box. A hole was made in the side of the box coinciding with the lens of the optical box through which the beam of light passed. The motion picture film ran through a groove on the inside of the box directly in the path of the light. Thus, any deflection of the beam of light would be photographed on the film. The film passed over a specially constructed sprocket which could be rotated by a pulley wheel either with the use of a constant speed motor, or by a crank turned by hand. The latter method was used during the last experiments when, from certain tests, it was found that the motor slightly disturbed the amplifying set. The film used was 35 millimeter Eastman Kodak negative during the early experiments, and later, 70 millimeter Eastman Kodak negative.

The oscillograph box contained, in addition to the element which was connected to the output from the amplifier, another oscillograph element and a signal marker. The auxiliary oscillograph element was used in the later experiments to provide a time line on the record. It connected to a lead fastened to the regular alternating current, which had passed through a Wheatstone resistance box. With this arrangement, a time line was photographed on the record by the same method as in the active oscillograph element, and with excursions of sixty cycles per second. In the earlier experiments, this timing device was not necessary inasmuch as the constant speed motor was used.

(2) Controls. In an experiment of this kind, the control or test records prove to be quite as important as the experimental records in ascertaining the validity of results. In fact the experimental data alone mean nothing without certain checks to show just what the records indicate. There were two groups of test

records taken in this experiment, one in which the dog was in circuit, and one with it outside the circuit. The tests with the dog in circuit included records taken while the animal was passive and receiving no stimulation. These records always gave a fairly steady baseline with which to evaluate the records taken under controlled stimulation. There were usually three or four of these check records made for each experiment.

The tests taken without the dog in circuit with the amplifier were of two kinds: *experimental tests* and *general* tests. The experimental tests were made, during the period of a given experiment, with a closed circuit. Under this condition, when various sound stimuli were given, any irregularity on the record would indicate that the records of sound stimulation were induced by mechanical vibration. No evidence was found from these tests that the record under closed circuit conditions and sound stimulation was any different from the closed circuit records under quiet conditions. Other tests were taken in this manner when the operating table was jarred, when the experimenters stamped on the floor, shook the dog, talked, and changed the illumination of the room. Stamping on the floor was the only disturbance which affected the record. To remove this disturbance, felt pads were placed on the floor of the operating room, on which the technicians stood throughout the periods of recording.

The general tests were made at times when no operation was being performed. These controls were designed especially to test the amplifier, and included: (1) records with the camera motor running and also with the hand turning of the film; (2) records with the first stages grounded and not grounded; (3) tests with the circuit open and with it closed; (4) tests made to measure the influence of switch contacts; and (5) numerous other technical tests made to establish the validity of the amplifier set-up. These tests showed that under certain conditions the use of the motor to operate the camera affected the amplifier and on the basis of these tests the motor was discarded in favor of a hand operation of the camera. Further tests showed that the bi-pass condenser between the first three stages and the last two stages of the amplifier introduced resonant frequency in the amplifier. This meant that when

a throw occurred on the record, it would trail off so that it always had a frequency of around 250 cycles per second. The condenser was therefore removed after the tests.

Further data are available to show that the records actually are from nerves. It might be conjectured that the fluctuations were induced by muscular contraction and therefore were muscle action currents and not nerve action currents. First, this criticism could not justifiably be advanced in light of the comparisons between muscle and nerve action currents which appear in the literature. The relatively slow frequency of the muscle does not compare with the frequencies of nerve action currents. The records taken in this experiment are identical with many of the reproduced pictures of nerve action currents. Second, the nerve preparation was insulated by bone from the muscles of the animal's head, which would make it impossible to pick up muscle action currents. Third, if the muscle action current could be picked up in spite of bone insulation, it would be expected that the magnitude of the record would vary directly as the distance from the musculature of the head. It will be noted later that the anterior sigmoid gyrus, which was situated very close to head muscles gave practically negative records throughout. Fourth, the fact that some of the records of largest magnitude were obtained when the dog was passive, indicates that the muscle action current is not inducing the record. Fifth, records taken with the motor anaesthetic, curara, in the neck of the animal, failed to result in any decrease in the magnitude of the records. Sixth, electrodes as close to a muscle as could be placed without actually touching, failed to pick up muscle currents. It might be pointed out in connection with this problem, however, that the records in all probability represent both sensory and motor nerve impulses, these two being in no sense as disparate as conventional nerve-muscle physiology would make them.

The value of these controls cannot be overestimated, as they reduced to a minimum chances for artifacts in the records. The relative amplitude and the throw-grouping on the records cannot be disputed. *The frequencies of the records, however, cannot be validated so directly.* It was impossible to test accurately *this*

phase of the records, except in a general way, without the availability of an oscillator. There is, however, indirect evidence regarding the genuineness of the frequency rates observed on our records. This evidence comes from a study of peripheral nerves, the frequencies of which were determined by Gasser and Erlanger to have a theoretical maximum of 1,724 impulses per second, made possible by an absolute refractory phase of .58 sigma. Adrian, however, has shown that the directly observed frequency does not exceed 300 to 400 per second. The frequencies which we observed on the records in the present study ranged from 180 to 700 impulses per second, which falls within the range cited by Gasser and Erlanger, Adrian and Zotterman, and others. From this evidence it seems safe to conclude that the frequency rate observed is valid, but as the checks mentioned have not been performed, and as there is no study of frequency in the cortex, frequency is ignored in this investigation.

A general anaesthetic was used during the operation as well as a local anaesthetic in the skin and muscles of the head. After the operation the general anaesthetic was allowed to wear off, and the animal given one hour and a half to two hours for recovery. During this time it was necessary to keep the surface of the cortex from drying and cooling. In the earlier experiments, heated Ringer's solution, fed by gravity from a large demijohn above the recording room, was used to irrigate the surface of the cortex. Considerable difficulty was experienced with this method in regulating the constancy of the temperature. Accordingly, in the latter part of the experiment a constant temperature water bath was adapted after Taft (24) in which the container of Ringer's was immersed and fed at a constant rate into the experimental room. This method gave a temperature constant within two or three hundredths of one degree. The irrigation of the exposed cortex was continued throughout the recovery period of the animal, and at all times except when actual recording was taking place.

(3) Electrodes. In most of the experiments silver electrodes were used, which rested on the surface of the cortex. These consisted of silver wires which passed through a bakelite block

fastened to the metal jack which clamped on the bone. The ends of the wires were looped and a sealing wax matrix filled in between the wires, forming a smooth, flat area, which rested on the cortex, and through which the surface of the wire protruded. The electrode wires passed into a common insulated cable, connected with a multiple contact switch. The leads were soldered to the lower part of copper plates in a bakelite base. Above the bakelite base ran a slide, which consisted of two insulated arms. The arms made contact with the copper points, which were so spaced that the arm made contact with only one at a time. The other arm of the slide passed over a corresponding set of copper points, to which the neutral electrode was fastened. This meant that if the arms of the slide made contact with the first point, a record could be obtained from the first active electrode and the neutral point. The switch also made possible a rapid shift from one electrode to another by a mere sliding of the switch from one copper point to the next. In some cases this change in electrodes was made while a single type of activity, on the part of the dog, was taking place.

(4) Stimuli. The four types of stimuli used in this experiment, all auditory, were produced by different instruments. First, the simplest kind of stimulation consisted of *whistling* to the dog. The experimenter would make several loud and short whistle sounds near the ear of the animal, as if calling to it. Second, a *low siren* was used, which gave an estimated variation in pitch from the lower limit of the range to about 400 d.v. This was produced by a cog-wheel fastened to a hand color-mixer. A celluloid strip, fastened in position by rubber bands, made contact with the cogs of the wheel, giving a sound of short duration and variable pitch when the wheel was rotated. For the low siren, the wheel was rotated fairly slowly, beginning with a slow speed and increasing gradually. Third, a *high siren* was used, the sound produced by the same instrument as before. In this case, the wheel was rotated very rapidly, giving a shrill and high-pitched sound. The estimated pitch, in this case, ranged from the lower limit to 2,000 vibrations. The siren method was a modification of that used by Forbes, Miller and O'Connor.

Fourth, a *quincke tube* was used, which gave a loud and shrill sound of 1,024 vibrations. The latter two forms of stimulation proved the most successful as far as eliciting a response from the animal was concerned.

V. Results

(1) Classification of records. For this experiment successful operations were performed on nine dogs. From these animals 78 action current records were taken from the various gyri of the cortex under different types of sound stimulation, and with the animal exhibiting different degrees of motor activity. These activity conditions, along with the sound conditions, will be discussed in detail. In making these comparisons it is necessary to group the records into types. In this classification the amplitude of the galvanic excursions on the record, the duration of large throws on the record, and the pattern of the record will be taken into consideration. On this basis the records fell roughly into four groups: those which were negative or showed no activity above the base-line (A, Fig. 1), and are given a numerical evaluation of 0; those which showed slight activity (B, Fig. 1), with a numerical evaluation of 1; those which showed medium activity (C, Fig. 1), with an evaluation of 2; and those which showed maximum activity (D, Fig. 1) with an evaluation of 4. The samples in Fig. 1 are only typical examples of the types, since great variability occurred within a given type. The numerical evaluation was necessary in order to find averages for the various gyrus positions.

(2) Stimulus situations. The stimulus situations can be grouped from two points of reference. The first of these is the type of sound stimulus. This grouping includes records from the various gyri with the high and low siren and the quincke tube, as well as a few with whistling as the stimulus. Therefore, one part of this section will be devoted to the correspondence between the type of record, the gyrus location and the type of sound stimulation.

More significant than the above grouping, however, is the classification of the types of response to the sound stimulation.

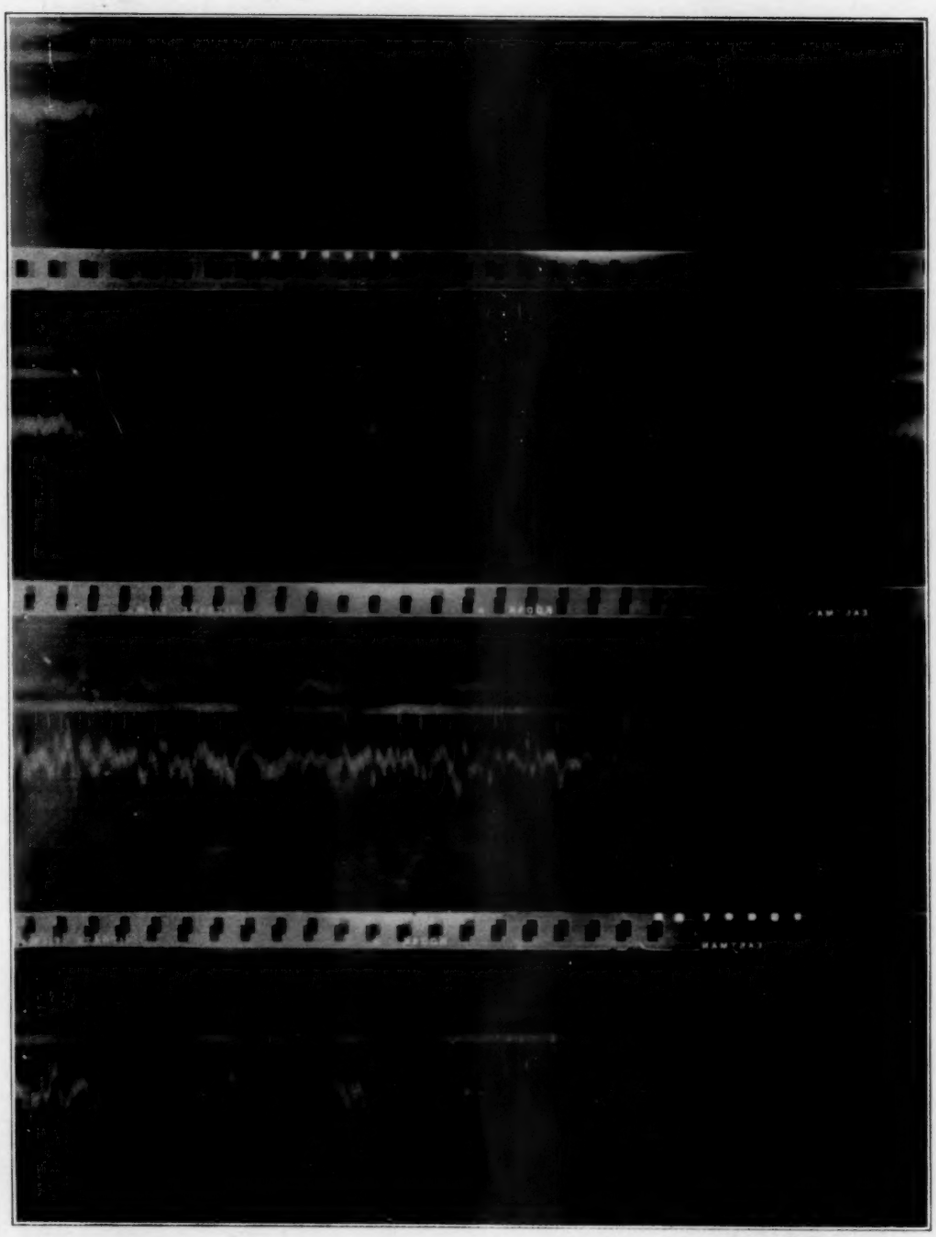

FIG. 1. Classification of Records by Amplitude. A, negative (0); B, slight activity (1); C, medium activity (2); D, maximum activity (4).

Selecting the dog's behavior as the point of reference, what types of records occur from the different gyri in the same behavior and stimulus situations? There are three classes of situations which come under this head.

(3) Relation between kind of activity and the records. The first activity-condition is *passive to sound* stimulation. Under this head fall cases where the dog was quiet, or practically so, during the period of recording. Under this head, also, fall cases where the dog changed its rate of breathing, or winked its eye, or flicked its ear. Thus the passive condition was not strictly passive, but showed no marked movement. The results from this condition are plotted on a map of the dog's cortex (No. 1, Fig. 2). The black dots indicate the actual location of the elec-

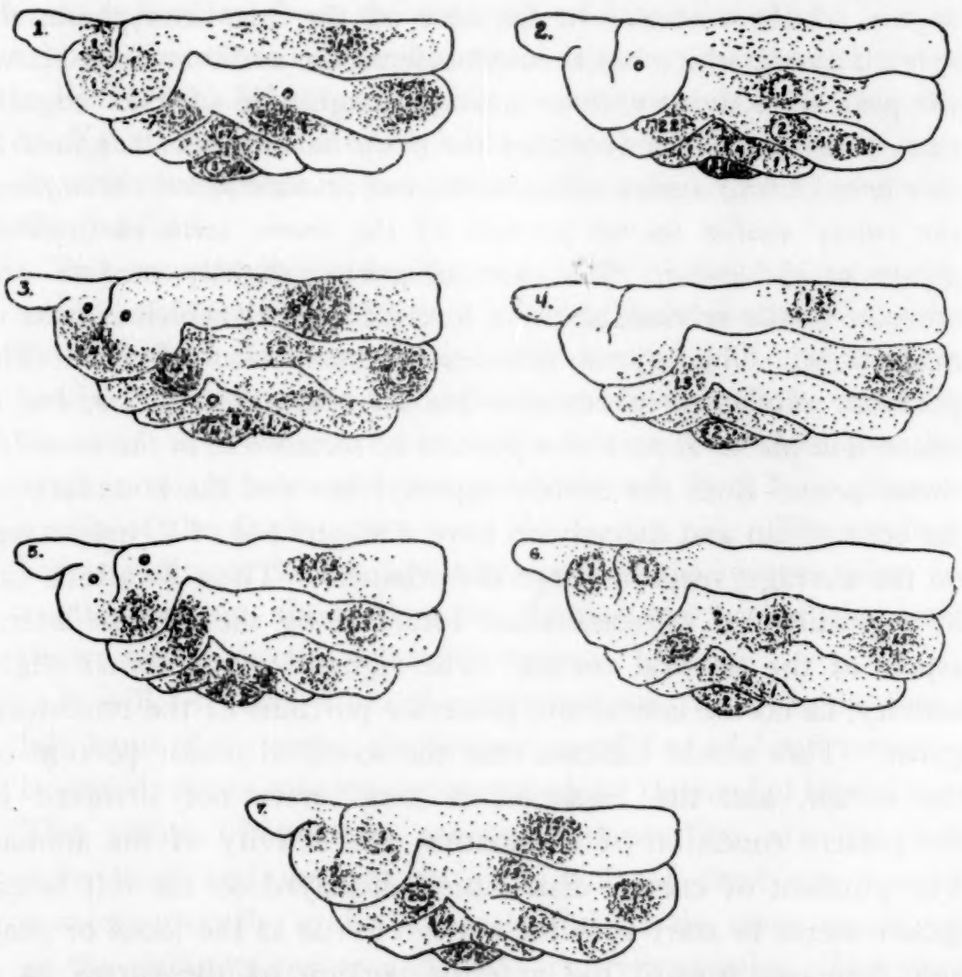

FIG. 2. Activity Maps of Dog's Cortex Showing Gradient of Magnitude per Area for Left Hemisphere. See text for explanation.

trodes from which the records were taken. The numbers on the dots are the average magnitudes mentioned above under classification of records (see Fig. 1). The shading in the drawing represents the average magnitude. Thus the lightest portions mean either that there was little or no disturbance on the record from that gyrus or that no records were taken from that gyrus under this activity condition. The moderately dark portions represent gyri from which medium-active records were obtained. The darkest portions of the map represent gyri where cortical action was maximum under this type of stimulation and with a passive condition of the animal. The map shows that the grossest disturbance under the conditions of sound stimulation, and with a passive condition of the dog, takes place in the medial lateral region of the cortex. In the case of the left hemisphere, the sylvian gyrus, which has been considered the auditory area, shows the peak of activity with an average magnitude of 3.0. Significant, however, is the fact that *the disturbance is not confined to this area during sound stimulation, but is distributed throughout the entire medial lateral portion of the brain, with the sylvian gyrus as the locus.* The coronal gyrus, slightly median and anterior to the sylvian, shows a level of activity which is next in magnitude. This gyrus receives an evaluation of 2.3. The posterior ectolateral gyrus also has an evaluation of 2.3, *but is situated at the most posterior portion of the cortex, in the so-called visual area.* Both the middle suprasylvian and the boundary of the ectosylvian and the sylvian have a magnitude of 2, indicating, on the average, medium large disturbances. These locations fall in a gradient of differentiation found along the median lateral aspect of the cerebral cortex. The sigmoid gyrus shows slight activity, as do the lateral and posterior portions of the ectolateral gyrus. This would indicate that the so-called motor portion of the cortex, and the 'association area,' were not involved in the present condition of stimulation and activity of the animal. The gradient of energy distribution displayed on the left hemisphere seems to start with the sylvian gyrus as the locus or peak and decreases toward the anterior portion of the cortex at a fairly rapid rate, while toward the posterior portion of the cortex

the decrease in activity is more gradual and seemingly continues at a fairly high level to the posterior ectolateral, before it decreases in the lateral gyrus.

The map of the right hemisphere does not present as complete a picture as that of the left hemisphere, due to the insufficient number of electrode locations, but the number of records on the points employed is large enough to warrant certain conclusions. The locus of activity is again situated toward the medial lateral position of the hemisphere. In this case, however, the point of highest activity is in the coronal and the ectosylvian gyri. The sylvian gyrus was not used as a recording point in this case so that this shift may not be significant. Records of a highly active character were obtained from the somaesthetic region, in this case, as well as from the anterior ectolateral region. We may suppose that these cyto-architectural regions represent high points in the cortical field that function in audition. It is curious, however, that the middle ectosylvian gyrus which supposedly has to do with movements in connection with audition, *is a low point in this gradient.*

The second activity-condition is that of *head movements to sound stimulation.* This set of conditions included any head movement of the dog, either a slight turning of the head, or a jerking movement, or a complete withdrawal of the head from the cone. The records taken under this condition, along with the average magnitudes and the gyri positions, have been plotted on a map of the dog's cortex (see No. 2, Fig. 2). The shading as before indicates the average magnitude of the records taken from a given region, the darker the shading the higher the activity shown on the records from that region.

It will be noted from the examination of the figure that the left hemisphere under the present condition of head movements to sound, shows maximum records along the medial lateral aspect. The points of greatest energy concentration are the middle ectosylvian and the sylvian gyri; both of these are practically maximum on the evaluation scale and are the areas usually cited as the auditory motor and auditory, respectively. The coronal and the middle suprasylvian gyri are active to a medium extent.

Areas yielding only small amplitudes include the anterior and posterior ectosylvian, the anterior ectolateral and the posterior suprasylvian gyri. Records taken from the posterior sigmoid gyrus are negative. There were no records taken from the right hemisphere.

The gradient of energy concentration under these conditions is very similar to that under passive conditions, except that the energy level seems to be somewhat higher. The high peak in the gradient is on, and surrounding, the sylvian gyrus and decreases from this point both posteriorly and anteriorly. It is curious that the posterior sigmoid, which is ascribed a motor function, should be totally negative when the dog was making movements during the period of recording. *This must indicate that this locus of the active portion of the cortex takes on different functional relations under different kinds of stimulation.*

The third activity condition is that of *gross body movements to sound stimulation.* Included under this head were any movements of a relatively extended character, such as general movements of the limbs, stiffening of the body, arching of the back, general struggling movements, or raising of the whole body from the operating table. The results of this grouping are plotted on the map of the dog's cortex (see No. 3, Fig. 2). As before the darkest shading indicates the grossest activity and the numbers indicate the average magnitude of the records.

It will be noted that the highly active areas are more widely distributed under conditions of gross activity than under either passive conditions or head movements. There are three points of maximum disturbance, *all of which fall along the medial lateral aspect of the cortex,* two of them anterior to the medial lateral line. The sylvian gyrus is again a high point in the gradient. The coronal and the lateral sigmoid gyri are the other regions of maximum activity. Although the latter position is bounded by a zero region on both the anterior and posterior portions of the same gyrus, this might be expected if the thesis is true that a gradient of activity extends along the medial lateral aspect of the cortex, for the part of the sigmoid gyrus mentioned as active falls in the path of the gradient. The posterior part of the cortex is only

moderately active, involving the anterior and posterior ectolateral, middle lateral, and the boundary between the ectosylvian and the sylvian gyri. Slight disturbance is shown on the posterior ectosylvian, and negative records on the anterior and posterior sigmoid and middle ectosylvian gyri. This would indicate that the so-called auditory, somaesthetic and lateral aspect of the motor areas have maximum energy concentration under the conditions of gross activity from sound stimulation, whereas the visual, part of the auditory motor, and the 'association' areas show a medium energy level under these conditions. The rest of the 'association areas,' the central portion of the auditory motor, and the rest of the motor areas have only very slight or negligible amplitude under these conditions.

Although there is some variability between the regions designated as maximum, medium and slight concentrations, under all three response conditions, results on the whole are strikingly consistent. In every case we have found an energy gradient extending along the medial lateral aspect of the cortex, with the peak in either the sylvian gyrus or regions near the medial lateral line. Further, it is significant that, throughout, the gradient has extended on either side of the peak of activity, both to the posterior and the anterior poles of the cortex. This extended energy range was graded, decreasing roughly as the distance from the medial lateral line posteriorly and anteriorly. Heightened activity always extended *farther* in the posterior direction than in the anterior direction, but in most cases, was not as high as the level found in the anterior direction. Also, under the conditions of gross activity, there were several areas of energy concentration, one in the sylvian gyrus and two anterior to that position. We may conclude from this analysis *that the auditory area is not all that is involved under the conditions of sound stimulation,* but represents a peak in the energy gradient that occurs under these conditions. The reason for this peak is probably the close proximity (as compared with any other portion of the cortex) of the sylvian gyrus to the auditory stimulus.

(4) Relation between type of sound stimulation and the records. The next grouping of the results will be that of kind of

sound stimulation with respect to the type of record and the gyral positions. The first type of sound stimulation is the *low siren.* The results from this stimulus are shown plotted on a map of the dog's cortex (No. 4, Fig. 2). The shading as before indicates the magnitude of the records on the gyral position, the darkest representing the highest activity. The map shows that the sylvian gyrus is one of the regions of highest energy concentration, although this level is only *medium* on the scale of evaluation we have constructed. The other high point is the posterior ectolateral gyrus. The coronal gyrus shows a slightly lower level than the two just mentioned and the anterior lateral and the boundary of the ectosylvian and the sylvian gyri are only slightly active. *The auditory and visual areas are the most active when the low siren is used as a stimulus.* One result is striking, with this stimulus, namely, that a relatively low energy level existed throughout. This must mean that the low siren is not a sufficiently disequilibrating stimulus to induce a higher energy level. It will be evident, also, that the energy gradient follows along the medial lateral aspect of the cortex and extends further in the posterior direction than in the anterior direction.

The *high siren* is the next stimulus condition to relate with the records taken on the various gyri of the cortex. The map of the cortex represents the results as before (see No. 5, Fig. 2). The map shows that the point of highest activity occurs on the sylvian gyrus, and is maximum on the selected scale of values. The coronal gyrus is next in activity, with the lateral sigmoid, middle lateral, posterior ectolateral and the boundary of the ectosylvian and the sylvian gyri next in magnitude of energy concentration. The slightly active portions of the cortex under this type of sound stimulus are the middle and posterior ectosylvian and the posterior suprasylvian gyri, while the anterior and posterior sigmoid gyri are entirely negative. The same general gradient of activity along the medial lateral aspect of the cortex is still to be observed. In this case, however, the active portion extends farther posteriorly and circles around to the middle lateral gyrus. The peak of activity is again in the sylvian gyrus with slightly lower activity, anterior, and still lower, posterior. *The main difference*

that can be observed between this grouping of the data and that taken under the condition of low siren, is the greater magnitude of the activity with the higher and shriller sound.

Under the condition of high siren, then, the so-called auditory area is active to a maximum extent through a large number of records. The coronal gyrus, to which is attributed a somaesthetic function, is next in activity. The lateral portion of the motor area, the visual area and the boundary of the auditory motor area, are all moderately active. The anterior and posterior portions of the motor area are entirely negative.

The third type of stimulus to be related with the types of records is the *quincke tube.* The results are given on the map of the dog's cortex (No. 6, Fig. 2). In the left hemisphere the coronal and the sylvian gyri were the regions of highest activity. These, however, were only moderately active. The lateral and posterior sigmoid, anterior, middle and posterior ectosylvian, and the anterior and posterior ectolateral gyri exhibited, uniformly, slight action. The regions of greatest activity are again scattered along the medial lateral portion of the cortex. It is noteworthy that the general level of activity under this condition of sound stimulation is not as high as in the case of the high siren. In general, the somaesthetic and the auditory areas give the greatest magnitude of response to the quincke tube, a fact consistent with the other two sound conditions.

On the right hemisphere, the anterior ectolateral and the coronal gyri show the greatest activity and this is maximum on the evaluation scale. In general, the gradient is located in the medial lateral region, but with one high region slightly more central than on the left hemisphere. It would appear, therefore, that the gradient is slightly different in the two hemispheres, because, on the left side, the area of heightened activity did not extend as far upward on the cortex. Whether the gradient on the right side extends as far down the sylvian gyrus as on the left side cannot be said, since records were not obtained. The coronal and the boundary of the anterior ectolateral gyri are the next in activity, which accords well with the findings on the left hemisphere. Little else, by way of conclusion, is justified from

the small number of records on the right hemisphere. The general level of activity in all the records under quincke tube stimulation, is lower than under the high siren stimulation.

Striking consistency of results is found when kind of stimulus is correlated with the records. The general level of activity with the low siren is always lower than with the high siren, and slightly lower than with the quincke tube. The high siren gave a large number of maximum records, whereas the quincke tube situation took its place between the other two. This fact accords well with the nature of the sound stimuli in each case and with the observations on the dog. The low siren, which was the least intense and disturbing, as judged by the human subject, gave the smallest records. The quincke tube, which was a fairly intense sound, but not as shrill or intense as the high siren, gave moderately active records. At the same time more motor activity in response to the sound stimulus was observed under this condition than under the low siren. The high siren consistently gave the largest record of the three stimuli, and at the same time, was the most intense, shrill and unusual sound of the three. The animal, likewise, showed more overt responses to this type of stimulus.

It seems important that the area of the cortex exhibiting the greatest activity under a given sound stimulus should be approximately the same under the three conditions, *the variation occurring in the level of the activity, not in location.* The amount of area covered by the gradient of activity under sound stimulation changes with a change in the stimulus. It is relatively large and stretches far to the posterior central portion of the cortex in the case of the high siren, and becomes more restricted in the case of the other stimuli. This would indicate that when a stimulus is introduced which disturbs the equilibrium of the neural field to a large extent *the disturbance is not only a change in the level of the peak of the gradient, but at the same time a change in the measurable extent of the gradient.*

(5) The relation between sound stimulation and type of record. The next grouping of the data includes all the records and all of the positions employed in the present study. This grouping will show the general activity of the cortex under sound stimulation,

without reference to kind of stimulation or the response that the animal made to the sound. The results are shown on a map of the dog's cortex (No. 7, Fig. 2) with the darkest shading indicating maximum activity. Inspection of the left hemisphere shows that during sound stimulation of any kind, *the sylvian gyrus is the most active portion of the cortex and that, in general, activity of maximum magnitude occurs along the medial lateral aspect of the hemisphere.* The so-called auditory area, then, is the high point in this lateral gradient, under the conditions of sound stimulation. The coronal and the posterior ectolateral gyri show fairly great activity. The visual and the somaesthetic areas are relatively high points in the gradient. The lateral sigmoid, of supposed motor function, and the anterior suprasylvian, of supposed auditory-motor function, are also relatively active. The ectosylvian gyrus, the anterior ectolateral, middle lateral and the posterior suprasylvian gyri show relatively low degree of energy concentration. These include part of the auditory-motor and the association areas. The regions of lowest activity occur in the anterior and posterior sigmoid gyri, which are called motor in function.

The data on the right hemisphere, although not as conclusive as those from the left, show the existence of activity toward the medial and lateral part of the hemisphere. In this case there are two regions of high concentration, one in the coronal and extending over the boundary into the anterior ectosylvian and the other in the anterior ectolateral. The other two regions investigated in this hemisphere are of relatively low activity, and occur in the middle ectosylvian and the boundary of the coronal and the posterior sigmoid gyri. The locus of activity is a little less lateral in this case than in the left hemisphere, but owing to the scarcity of data, this fact may be insignificant. In general the two hemispheres yield similar results as far as the distribution of activity is concerned.

All of the data presented in this study bear out the point that under conditions of auditory stimulation there is a gradient of cerebral activity, as recorded by the action current technique, which extends along the medial lateral aspect of the cortex. The

locus or high peak of activity in this gradient is found, in the central portion, or so-called auditory area. Activity immediately anterior to this peak is greater than immediately posterior, but does not extend as far anteriorly as posteriorly. There is a general decrease in activity in both the posterior and the anterior direction. In the direction central to this lateral gradient, there is a rapid tapering of the gradient. Under conditions of intense sound stimulation, as with the high siren, the general level of activity is increased and at the same time the area covered by the gradient is increased. Under conditions of gross bodily activity the gradient is more extended, and at the same time becomes more complex in nature, with several regions of maximum activity.

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GROSS DIFFERENTIAL ACTIVITY OF THE DOG'S CORTEX AS REVEALED BY ACTION CURRENTS[1]

by

S. HOWARD BARTLEY

CONTENTS

I. INTRODUCTION
II. HISTORY
III. METHOD
IV. RESULTS
V. INTERPRETATION
VI. SUMMARY

I. INTRODUCTION

The purpose of this investigation was to bring to as thorough a test as possible, by the action current technique, a general field theory of cortical activity. By a field theory is meant first, that the cortex, as a whole, functions at all times in response to all stimuli. It is a mass action theory. Second, it is supposed that in place of conventional views concerning localization of function the part played in the whole by a given area of the cortex can best be described in terms of cortical gradients. Each part, then, functions in accordance with its position in the particular gradient that happens to be functioning at the time. Third, a field theory presupposes that the laws of brain activity are laws of the balance and unity of 'fluid' systems of energy. In other words, they are the laws of dynamics. Fourth, a field theory presupposes that the activity of any given part of the cortex evolves in the course of growth and differentiation which determine the functioning of the sense organs as well as the functioning of different cortical areas. And

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finally, a field theory presupposes that any mechanical, mosaic or synthetic theory of neural activity is futile, neither fitting the facts nor resting upon sound logic, and that the concept of reflex action as ordinarily defined must be supplanted by the concept of configurational response (1).

A description of the apparatus and certain aspects of the method used in this investigation have already been discussed by Bartley and Newman (2). A further description may be found in the preceding article by F. Theodore Perkins whose work on the auditory area was done in collaboration with the present study, using the same apparatus and the same animal subjects.

II. History

Willis (3), around 200 years ago, attempted to assign functions to different parts of the brain, considering it an assemblage of organs. In 1805 Gall (4) assumed that there were at least 35 different faculties of mind each one of which was located in a particular part of the brain. In 1842 Flourens (5) credited Gall with being a skilled anatomist but opposed the compartmentalization of the brain in order to account for " faculties ". He insisted that the brain was functionally an indivisible unit. Up to the time of Broca (6), Longet (7) and others such as Magendie (8), Matteucci (9), Flourens (5), Van Deen (10), and Schiff (11), in agreement with Flourens had believed that cerebral functions were not localized, but from the time of Broca practically to the time of Franz (12) and Lashley (13) localization of function was in vogue.

Meanwhile the cell theory of the organism had been formulated beginning with Schleiden and Schwann (14) in 1838 to 1839. The cell theory had become well established by 1891, when Waldeyer (15) introduced the term neuron in stating his general theory of nerves. Neural theory, therefore, inherited the logic of the more general cell theory and reached perhaps a climax in Sherrington's (16) *Integrative Action of the Nervous System in* 1906.

Theories of brain functions may be divided roughly into four classes: (1) cerebral unity theories; (2) aggregation theories;

(3) association area theories; and (4) special area theories. Longet, Magendie, Matteucci, Flourens, Van Deen and Schiff adhered to the first type of theory. However, their conception of unity was that of homogeneity. An example of the aggregation theory comes from Munk's view that there are a number of 'sensory spheres'. This conception accords well with the mechanistic attitude that unity is to be derived by a process of synthesis.

The third group of theories, the association group, need not be discussed here beyond the extent of noting that various parts of the cortex were assigned specific motor and sensory functions while large, intervening regions were assigned to association, the process of integrating the functions of the sensory and motor areas. Throughout all of these theories, which, perhaps, have been more common than any other one type, the assumption is made that specific and independent activities somehow get put together by means of a special integrating mechanism or combination of such mechanisms. The whole is explained in terms of the parts.

Hitzig assumed that intelligence was to be found in all parts of the cortex but that thinking demanded a special organ which he located provisionally in the frontal lobes.

In more recent times, aside from the work of Lashley (13) which is so well known as not to require a special review here, there have been at least three lines of investigation that bear upon the present study. The first of these is the work of Head (17). Obtaining his original cue evidently from Jackson (18) Head proposed the thesis that sensory nerve impulses underwent three rearrangements on their way to the cortex: in the spinal cord, nuclei in the posterior columns of the cord and the medulla, and the thalamus. Evidence in support of this theory came in large measure, it was thought, from neuropathology. Second, Magnus (19), in his far reaching work on posture, found that the so-called local reflex was by no means a fixed or stereotyped phenomenon as was popularly supposed. His results indicated that many of the so-called reflexes are 'attitudinal' or 'postural' in character, and that just how a local group of muscles will

respond depends upon the attitudinal reflexes that are functioning at the time. There is evidence that decerebrate animals respond 'segmentally', and not in terms of the limited, local reflexes which supposedly had been observed in the past. Third, there is the work of Dusser de Barenne (20) who observed the effects of strychnine on the surface of the cortex in cats and monkeys. When areas commonly supposed to be motor in function were treated with strychnine the animal showed various signs of hypersensitivity on different parts of the body. For example, with strychnine on the posterior sigmoid gyrus (motor) the cat would bite at the forepaw on the contralateral side; it would lick its forepaw, or seize it in its teeth and shake it. It would resist violently any attempt on the part of the experimenter to touch the leg. Dusser de Barenne believed that the cat was suffering pain both cutaneously and in the muscles and joints. He also found that the consequences of strychnine application on the same part of the cortex yielded different results at different times in the same animal. Thus the problem of specific functions for specific areas seems in greater doubt than ever. It is evident that sensory phenomena can be elicited from motor areas or at least, as Munk had held, that there are regions of the cortex that are both sensory and motor in function. Ever since the beginning of the faradic method of cortical stimulation it has been known that motor phenomena can be elicited from stimulation of the so-called sensory areas. In spite of this fact the dichotomy has persisted in theory between motor and sensory functions of the cortex.

III. Method

In general the action current method in this experiment consisted of placing an active electrode (1/256 sq. in.; silver) directly upon the cortical area to be investigated, and a neutral electrode (1/5 sq. in.) upon an 'indifferent' structure such as a bone of the skull over the anterior end of the lateral and ectolateral gyri. (This procedure may be varied by the use of two 'active' electrodes, and by inserting the electrodes into the cortical tissue.) The action currents are led off the brain through a vacuum tube amplifier, hence to an oscillograph element. The

deflections of the oscillograph are in turn photographed on moving picture film. The present method was not used to investigate the detailed features of individual action currents. (*Cf.* Gasser and Erlanger [21] for studies of wave form and frequency of single action currents by the cathode ray oscillograph method.) The chief purpose was to explore the cortex in a preliminary manner for the distribution of action currents, their amplitude, and gross wave-form, over fairly extended periods of time, and during different types of behavior.

An electrode holder carrying at least four electrodes was used, the latter located at scattered places on the cortex and used interchangeably by means of a switch. Rapid changes from one cortical region to another could thus be made while the animal continued a given movement. Both hemispheres were examined by the method just described, although by far the greater number of records were taken from the left. Care was taken that the inactive pole lay above the meninges in order to insure a complete grounding. Both electrodes were fastened in such a way that the contacts were not altered or broken by movement of the animal. For other various controls and cautions employed in this study the reader is referred to Bartley and Newman (2) and to Perkins (22).

In the present study operations were performed successfully on 20 dogs. After 1½ to 2 hours had been allowed for recovery from the operation and the effects of the general ether anaesthetic, the animals were stimulated during the period of recording with three general classes of stimuli: (1) Painful, in the form of pinching the animal's tail or back. (2) Motor, by rolling the animal's body back and forth on the operating table, to which it was fastened during the period of recording. (3) Visual stimulation in the form of a single stationary bright light on a dark field. (This stimulation was applied either as a constant light, moving light or intermittent flashes.)

It is at once obvious that the animal would not react to these various stimuli in the same way each time and as a result it was necessary to record during the experimentation the activity of the animal in response to the particular stimulus. With these data

it was possible to classify the behavior of the animal with respect to the stimuli cited above. This classification included 17 divisions which are listed as follows:

1. Dog Passive with no Experimental Stimulation.
2. Dog Passive with Brightness Stimulation.
3. Dog Passive with Motor Stimulation. (Experimental Motion of Head.)
4. Dog Passive with Motor Stimulation. (Experimental Motion of Body.)
5. Dog Passive with Pain Stimulation.
6. Dog Wincing to Pain Stimulation.
7. Forelimb Movements to Pain Stimulation.
8. Limb Movements with Motor Stimulation.
9. Hindlimb Movements with Pain Stimulation.
10. Gross Movements to Pain Stimulation.
11. Gross Movements to Motion of Body.
12. Gross Movements to Brightness Stimulation.
13. Wincing to Brightness Stimulation.
14. Head Movement to Pain Stimulation.
15. Head Movement to Motion of the Body.
16. Spontaneous Movements of the Animal.
17. Experimental Injury to the Sensori-motor Area.

Out of these 17, 10 behavior situations were repeated a sufficient number of times to permit the construction of a map for each, pointing out the loci at which both high and low amplitudes in the records were found. Scattered records only are to be had for the other behavior situations.

The results of these experiments can be grouped from four points of reference, namely, (1) the stimulus situation, (2) the animal's behavior, (3) the places on the cortex at which the record was taken, and (4) the amplitude of the disturbance on the record.

For each behavior situation, the records were grouped according to the cortical positions from which they were obtained. Fifteen general areas were explored from which 1 to 13 records were taken. Records exhibiting very little or no activity were

assigned the value of zero; those of progressively larger amplitudes were given values ranging from 1 to 4. All areas are not represented with an equal number of records since the animal would not always respond in the way intended. The consistency in amplitude value for the different experimental conditions found after all the data had been obtained, was very striking.

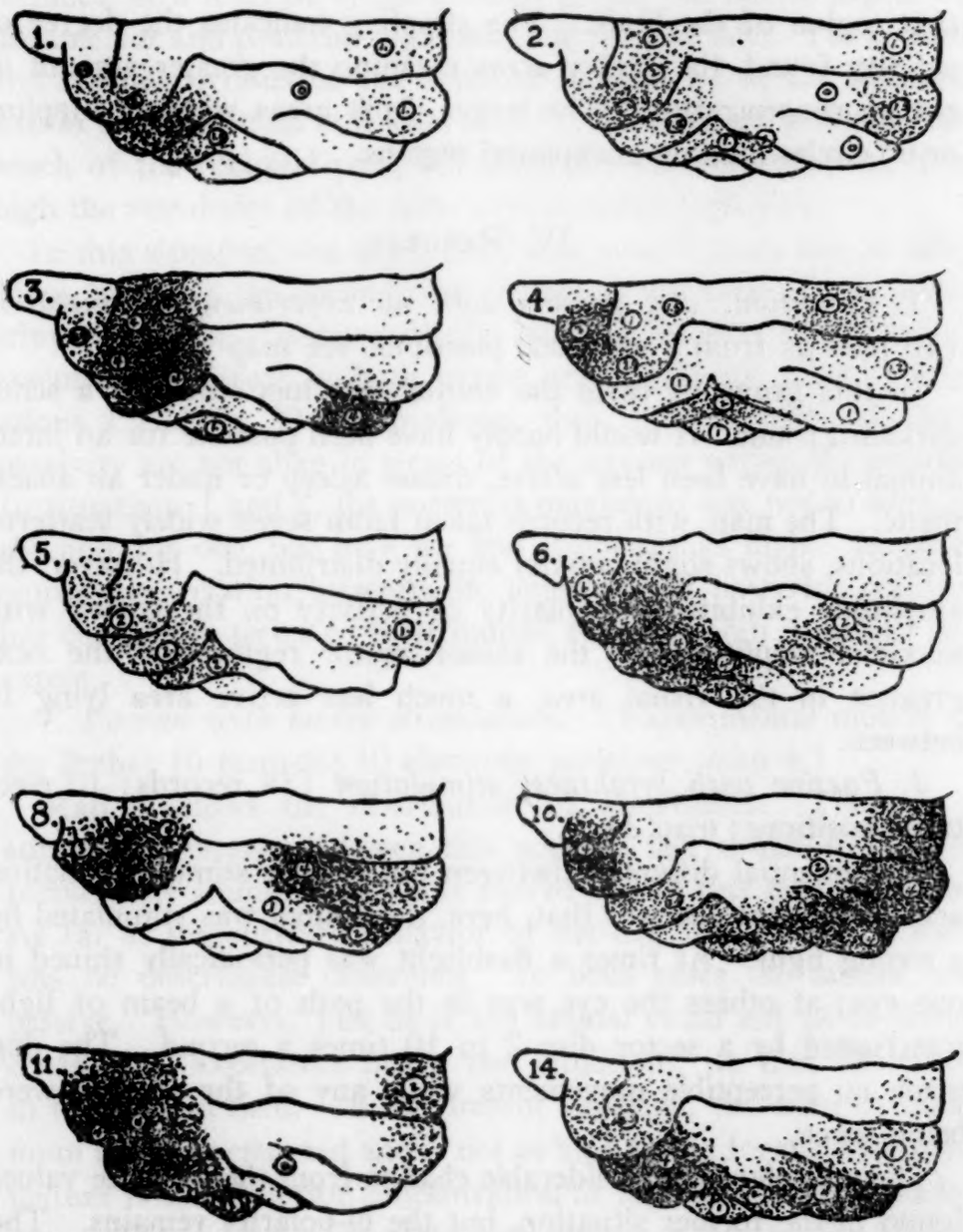

FIG. 1. Maps of Dog's Left Hemisphere Showing Gradient of Activity to Different Stimulus and Response Conditions. See text.

The data obtained for a given behavior situation were drawn up in the form of a map in order to make clear the differences in cortical activity. It will be noted from Fig. 1 that the maps picture the dorsum of the animal's left hemisphere. The circles on the various gyri indicate the approximate centers of the areas explored. Within the circles are figures giving representative amplitudes of the action currents (scale from 1 to 4) found in that region of the brain. The stippling indicates the degree of activity found, the darker areas meaning the greater amount of energy concentration. The larger blank areas with no stippling or no circles indicate unexplored regions.

IV. Results

1. Condition: dog passive with no experimental stimulation (16 records from 7 electrode positions, see map 1, Fig. 1).

In this group of cases the animal was motionless in a semi-darkened room. It would hardly have been possible for an intact animal to have been less active, unless asleep or under an anaesthetic. The map, with records taken from seven widely scattered locations, shows slight activity equally distributed. However, the amplitude exhibits a bi-polarity of activity on the cortex with maximal amplitudes in the sensori-motor region and the next greatest in the visual area, a much less active area lying in between.

2. Passive with brightness stimulation (38 records; 10 electrode positions; map 2).

The essential difference between the former stimulus-situation and the present one was that, here, the animal was stimulated by a strong light. At times a flashlight was periodically shined in one eye; at others the eye was in the path of a beam of light interrupted by a sector disc 2 to 10 times a second. The dog made no perceptible movements while any of the records were being taken.

The map shows a considerable change from the absolute values found in the former situation, but the bi-polarity remains. The anterior maximum is not so high, while the posterior is higher.

Obviously the balance of the whole cortex has changed while *the general pattern still exists.*

3. Dog passive with motor stimulation. (Experimental motion of the animal's head; 16 records; 7 electrode positions; map 3.)

From map 3, it will immediately be seen that in this situation there is an anterior and a posterior maximum. The former includes, at a level of 4, the coronal gyrus, the lateral aspect of the anterior and posterior sigmoids, and the cruciate. The central and medial portions of the anterior sigmoid gyrus are included within the maximum at a level of 2.5. No data are available for much of the occipital pole, but since the lateral portion of it is high the remainder of the pole is presumably high also.

In this situation, the dog's head was moved from side to side. Here, although the animal was passive at the time of the initial stimulation, the character of the anterior somatic maximum is essentially different in both extent and amplitude than in situations 1 and 2. The map shows, then, that all cases of overt passivity are not alike in terms of the stresses within the animal. In situations 1 and 2, the posterior maximum was not as high as the anterior one, but here we find it equally as high. In other words, the relation between the anterior and posterior maxima has changed in terms of their mutual relations both in height and extent.

4. Passive with motor stimulation. (Experimental motion of the limbs; 16 records; 10 electrode positions; map 4.)

Map 4 shows the distribution of amplitudes. There is a stimulus difference between this and the last situation. In the former, the animal's head was moved and in this case the limbs. As far as the outward behavior of the dog was concerned there was no describable difference. In both cases the animal was passive. However, just as if the animal could tell us of differences in its experience in the two situations, we find differences in the cortical field. In the present situation, the anterior maximum is more restricted and is not as high in the former situations, neither is the posterior concentration as high as it was in the last case. The animal apparently was disturbed less by the moving of its limbs than by the moving of its head, for either or both of

two reasons. First, the anterior end of the animal may ordinarily be more sensitive; second, the animal is already disturbed at the head end by the operative wound.

5. Passive with Pain Stimulation. (5 records; 4 electrode positions; map 5.)

It will be seen from map 5 that the material for this situation is scanty, but in the few available records some idea of the amplitude distributions can be obtained. The map shows again a bi-polarity. The level of the posterior maximum is only medium-high, suggesting that though the animal was given stimulation intended to be painful, there was only a moderate result. Outwardly, the animal was passive, and as far as the cortex was concerned, there seemed to be less kinetic energy involved than when the head was moved. The stimulation seemed in this case to be no more effective in disturbing the animal than moving its limbs, though what disturbance there was furnished a different pattern than before, as attested by the maps of this situation and situation 4.

6. Wincing to Pain Stimulation. (8 records; 7 electrode positions; map 6.)

Map 6 shows the results from wincing to pain stimulation. The locations explored are more numerous in the anterior half of the cortex. The anterior maximum extends into the auditory area where a level of 3 is found in comparison to that of 4 in the middle and anterior ectosylvian gyrus and the coronal and lateral sigmoid gyri. This situation represents cases in which the intended pain stimulation was evidently becoming supraliminal. As outward evidence of response, there was wincing or very slight squirming. Correspondingly, the somatic cortical maximum was widely extended.

8. Leg movements with Motor Stimulation. (Artificial movement of the legs; 9 records; 7 electrode positions; map 8.)

Map 8 at once suggests both anterior and posterior maxima, though the fact that no records were obtained from the area between the cruciate gyrus and the anterior ectolateral limits the evidence for the posterior maximum. Neither are there records from the coronal gyrus. Thus one cannot make a rigid compari-

son between the extent of the anterior maximum in this situation and any of the others. The maximum is high, however, where recorded. The few records obtained from the occipital area indicate that the concentration is high there also. It is probably true, then, that whenever the animal begins to make movements involving a large part of its musculature such as in walking, pawing, and in making sweeping head movements, the occipital region is involved more appreciably than in passive situations. This is interesting when one reflects that the animal was not walking about but was strapped in a harness, in a darkened room. The interesting question is raised whether this occipital activity means the functioning of visual imagination, or whether intensive voluntary activity requires increased energy from the occipital region, regardless of a visual aspect. The latter view seems the more plausible since imagery seems to be barely a supraliminal process, thus indicating that its functioning does not require extensive differentials of energy.

10. Gross Movements with Pain Stimulation. (19 records; 9 electrode positions; map 10.)

Map 10 shows a greater amount of activity than any previously described. The usual maxima are present; in this case both have an amplitude level of 4. Records from a wider variety of locations are available for the posterior maximum than for the anterior one. This high level is found to extend into the auditory area, making it a part of the posterior concentration. The height and breadth of the posterior maximum in the present situation suggests that along with the increased overt action the dog attempts to see as it struggles to free itself and to jump from the operating table. It would not be surprising if intense motor activity involving vision, or attempts to see, should reveal a very high energy level in the so-called visual cortex inasmuch as this part of the cortex presumably has much to do with the innervation of the muscles *via* the 'motor areas'. If the behavior were *emotional* in character, as was obvious in this situation, the occipital pole would probably show all the more kinetic disturbance.

11. Gross Movements to Motion of the Body. (32 records; 9 electrode positions; map 11.)

According to map 11, it will be seen that the majority of the gyral positions that were investigated are in the somatic field. While the evidence is limited concerning a maximum at the occipital pole, it is apparent that there are two maxima as usual, one frontal and the other occipital. The anterior maximum is widely extended, high, and involves the auditory area.

The results from a study of the maps showing the relative amplitude of the records with respect to behavior situations and the gyral positions on the cortex, may be summarized as follows: first, the cortex functions as a unified field, since an isolation of particular areas does not appear in the results. The level of any area seems to depend as much upon the distribution of energy in the rest of the cortex as upon peripheral conditions impinging on any small area. For example, the first five situations brought out differences in the levels and extents of both the anterior and posterior maxima. Aside from the fact that in all these cases the maxima existed, the maps were strikingly different in pattern. In each situation, the animal was passive as far as overt movement was concerned. The motor periphery in each instance was constant, but the cortical distribution maps showed differences in the motor or somatic arc. *Thus it is impossible to predict from what is occurring at the periphery to activity in the somatic cortical area and vice versa.*

Furthermore, the auditory area in three of the situations was found to be at a maximum, with no differential auditory stimulation. Corresponding irregularities between the visual area and visual stimulus situations were also observed. Maximum kinetic energy was recorded from the visual area with the animal in dim illumination and in complete darkness.

Second, the maps show that for any particular area, there is a changing set of relationships with the cortex as a whole.

Third, most of the maps represent two maxima in energy distribution; the remaining few indicate strongly that such a distribution would appear with additional data. One of the points of maximum distribution is situated in the somatic projection area in

the anterior part of the cortex while the other point of maximum distribution covers the posterior half of the cortex with its peak in the occipital pole.

Fourth, the peaks of these maxima vary from one stimulus situation to the next but in a general way are similar between stimulus situations.

Fifth, the area of low energy concentration is constant throughout the data studied and corresponds to the histological region anterior to the parietal pole, described by Campbell in 1905.

V. Interpretation

Throughout the description of the results of this experiment it has been obvious that current conceptions of cortical activity have received little support. Rather, throughout, a new type of theory has been indicated in a general way but as yet has not been discussed in sufficient detail. This newer theory may be designated as a field theory since it assumes that cortical activity is explicable only when the nervous system, and in particular the cortex, is treated as an indivisible, functioning unit. This in turn presupposes that the function that a particular area will have depends paramountly on what the remainder of the cortex is doing at the same time.

The current theories of brain functioning are based upon one major logical fallacy, namely, that the function of the organism is to be explained by the addition of the functions of a number of parts which by definition are discrete and separate from one another. Such a view is given the name atomism and in the history of physiological psychology has never failed to raise more problems than it solved. On this view a strict correlation between structure and function was attempted as the inevitable. Needless to say, such a correlation has proved a will-o'-the-wisp. Such a view also has led to the unfortunate experimental conception that when all but one condition was held constant in an experiment, those constant conditions were eliminated from the explanatory picture. As a consequence the view became current that the so-called visual region of the cortex (or any other) could function

alone and isolated from all other parts of the cortex and that vision would remain when the rest of the cortex was removed.

A field theory, on the other hand, assumes that a behavior-act is unitary, in all its aspects, from its origin to its completion. The cortex, therefore, must be regarded as an indivisible field which exhibits differences in potential under varying conditions. The fact of a difference in potential, that is, a high potential in one area and a low potential in another area, necessitates a field within which the high and the low potentials are related. When description necessitates terms which do not refer to energy distribution, then the description refers to the *phenomenological* aspects of energy and not to its dynamics, as such.

From the results of this experiment there has appeared evidence that the visual and somatic areas are the primary differentiations of the cortical field. The question at once arises as to the nature of further differentiation of the cortical field, some of which necessarily occurs within the two areas of high concentration. One might expect specific qualities such as pain, cutaneous pressure, kinaesthesis, cold, and warmth to depend in part on differentiation within the gyri in the anterior part of the cortex. However, this possibility does not necessitate segregating this portion of the cortex functionally from the remainder of the cortical field, in order to account for the specific qualities just cited. Structurization of cortical energy with respect to somatic modes of stimulation might very well extend across the cortex but take place in the somatic region *more than* in other parts of the system, because of the greater amount of energy reaching the cortex at this point from the somatic receptors. In similar fashion, the visual cortex might represent a maximum structurization of energy with respect to incoming impulses from the retina while energy necessary for vision might extend, gradient-wise, across the cortex.

If this view is correct, then the so-called sensory areas are peaks in transcortical gradients of some sort, but cannot be said to have specificity of function. The response patterns pervading the entire cortex might be defined as specific with respect to

definite modes of stimulation, but not specific with respect to area and internal structure.

It is obvious that a given area has more than one function. Indeed there is no reason not to suppose that its function varies with the total stimulus-situation confronting the animals, a conclusion not inconsistent with the results of this investigation. This fact was most clearly indicated with respect to the visual and auditory areas, which, in the absence of stimulation from the corresponding peripheral organs, revealed a maximum activity both with the dog passive and active. Intensive stimulation of the dog's eyes did not raise the energy level of the visual area, under the conditions of the experiment, as much as kinaesthetic stimulation did, or voluntary movement of the animal. It seems unmistakably clear that the initiation of movement always involves the visual area, and at times the auditory. This is to be expected if parts of the body are moved in accordance with laws of dynamics, and no other theory is conceivable. There is no way to envisage the initiation, direction, and termination of a movement other than in terms of the dynamics of ' fluid ' fields, where movements occur down a gradient of potential in the course of resolving a differential.

Moreover, the fact that a given area has more than one function offers no difficulties to a dynamic conception, for the action patterns are structured by patterns of stimulation, and in accordance with the demand for internal adjustments between differentials set up by the stimuli. In fact the same area might very well be doing several things at once, if the functions involved different periodicities, as in case of radio waves.

There is evidence throughout that the local differentiations at the poles of the cortical field depend upon each other as much as upon the corresponding peripheral organs. This, too, is to be expected in terms of a field theory, because every part of a ' fluid ' field is continuously ' responding ' to every other, and depending upon every other for its contributions to the functioning of the whole. Where routes to and from the cortex are large, and direct, maxima of energy levels are to be expected, under the law of least action, and this is where the highest energy levels were

consistently found in the present experiment. In these regions—motor, somaesthetic and visual—there is obviously a maximum of differentiation, and differentiation requires available energy. It is not surprising that when the energy level became higher in the one, the other became higher, also, when the whole cortex functions as a unit. The highest levels are to be expected where there are the greatest amounts of differentiation.

The experiments of Dusser de Barenne, previously cited, justify the growing suspicion that the so-called motor areas in the anterior half of the cortex are not exclusively motor in function but are sensory as well. This result is in accord with the non-localization required by a field theory. The results in the present study harmonize completely with these findings in that the cortex exhibited a bi-polarity in which the anterior pole took on a somatic function rather than a distinct motor or sensory function or a combination of motor and sensory functions, and where the visual and auditory areas obviously took on motor functions. If the law of determined action is valid, this is to be expected, since it requires a 'whole' to 'move' a 'part'. (It requires a whole gravitational system to 'move' a falling body; a whole atmospheric field to produce an air current; and, as Coghill and others have shown, a physiological field, polarized, to make possible a nerve current or discharge.)

Lashley has reported an extensive series of experiments which substantiate a field theory of cortical activity. In interpreting the results of his experiment, Lashley presents three theoretical principles, namely, equipotentiality, mass action, and dynamic equilibrium of brain areas. He shows that behavior disturbances are roughly proportional to loss of cortical tissue but continues to postulate, to a certain extent, localization of function in order to account for the fact that injury to the occipital pole was more critical for brightness and form discrimination than injuries elsewhere. Lashley has not made adequate use of the principles with which he began. The present concept of the bi-polar distribution of energy adequately explains the results of the cortical experimentation carried out by Lashley. A given area derives its function from its relation to the field as a whole. When loss of

the visual cortex destroys vision it means only that *some* of the energy *necessary* for this performance is lacking, and as a consequence the activity will not take place. This interpretation does not mean that the activity depended on this area alone or upon this area more than upon the brain as a whole. It is necessary to suppose only that sufficient amounts of energy necessary to carry out form discrimination no longer exist at the pole. At the same time, the most complicated visual function depends just as much upon the anterior pole as upon the posterior pole and in fact upon the entire transcortical gradient.

It merely means that successively larger amounts of tissue must be removed in order to produce the same effect, the farther down the gradient the lesion is made. In other words, if 10 per cent of the cortex, removed at the visual pole, were sufficient to destroy form vision, that 10 per cent might represent, say, 20 per cent of the energy available in the whole cortex for visual response. To destroy this same amount at the lower end of the gradient might require a lesion covering 30 per cent of cortical area, because of the lower degree of concentration of cortical energy, in that region, with respect to visual functions.

The conditioned reflex school, under the guidance of Pavlov (**23**), has performed many studies on cerebral function. The interpretation of these experiments may be summed up in the following statements taken from Pavlov: "The cerebral cortex can be represented as an exceedingly rich mosaic, or as an extremely complicated 'switch-board'. One group of cortical cells must be connected with one definite activity of the organism, another group with another activity. . . ."

"The existence of localization of function in the cortex is in some cases sufficiently proven by the evidence of structure alone, definite receptor elements having been shown to stand in connection with definite cortical cells. The study of conditioned reflexes has shown, however, that a conditioned reflex appears at first in a generalized form, *i.e.*, that excitation irradiates from its point of initiation to embrace also cells belonging to other receptor elements beyond the boundary of the area of the cortex primarily connected with the stimulated receptor; the problem

becomes still more complicated when we take into account also the subsequent concentration of excitation upon its point of initiation." (Pavlov, I. P., *Conditioned Reflexes.* London, 1927, pp. 219–220.)

These statements portray the position which Pavlov takes, namely, that cortical activity is to be envisaged as a mosaic of independently functioning parts each having a particular function distinct from any other part. Such a view is sheer atomism. It begs the problem of organization and unity by assuming unity to be a mysterious synthetic product—order coming into existence by summating bits of chaos, a view as archaic as it is absurd. In his attempt to narrow down the conditions of behavior Pavlov has committed the logical fallacy of considering the limited reaction as a discrete process with no relation to the rest of the activity of the animal. The actual situation is that the stimulus-conditions *have been limited*, but, limited or not, an entire organism must respond to the stimuli. Had Pavlov been guided by a field theory instead of by an atomism, much of the ardent labor of the conditioned reflex school would have produced more fruitful and far reaching results. The significance of the 'generalized reflex' and of differentiation would have been obvious to him at once, and would have led to an abandonment of the reflex theory of behavior.

VI. Summary

(1) The dog's cortex is active when the animal is apparently passive and under no particular differential stimulation. The records lead to the conclusion that the so-called passive animal exhibits a pattern of cortical activity of essentially the same order as exhibited by the active animal. In other words, there seems to be a basic pattern operating under all conditions of behavior and that any experimental stimulation of the animal under controlled conditions does no more than modify this pattern. This is a basic pattern which pictures the adjustment of the cortex as a whole to the animal's environment. This pattern is characterized chiefly by a concentration of energy extending from the

anterior to the posterior pole, through the auditory area, with a maximum at each of the poles.

(2) Under brightness stimulation, with the dog passive, the level of concentration rises in the occipital pole and at the anterior pole shifts toward the median aspect of the hemisphere.

(3) It follows from the preceding that the whole cortex, at least when intact, is involved in responses to brightness.

(4) When the dog is stimulated over proprioceptive channels by artificially moving its head from side to side, and remains passive, the level of the anterior maximum rises in a striking fashion, and also increases in area, which perhaps may mean that moving the head caused pain. However, the posterior maximum rises *with* the corresponding increase in the anterior pole.

(5) The cortical pattern is modified to a less extent by moving the dog's legs artificially. Neither the anterior nor the posterior maximum undergoes so much of a change toward greater extent and magnitude. On the other hand, the anterior pole becomes more restricted and suffers a loss in magnitude of disturbance as compared with the consequences of head movement.

(6) In the situation of moving the head and legs artificially the peak of the anterior concentration shifts medio-anteriorly, that is, from the coronal to the anterior sigmoid gyrus. Curiously, the sigmoid gyrus is ordinarily ascribed a motor function. In this situation, however, the animal was not actively resisting the stimulation. It would seem therefore that activity in this region represents a sensory function as much as it represents a motor function. This is the region that showed almost no activity with the dog passive and under no differential stimulation (situation 1). The maximum at the posterior pole spreads in a lateral and anterior direction almost as far as the auditory region and is higher in the region of the middle lateral gyrus than in the case of brightness stimulation with the dog passive. The total picture suggests again mutual dependence of activity at the two poles regardless of the mode of experimental stimulation.

(7) Since the cortical pattern under pain stimulation with the dog passive is similar to the pattern where the dog was passive

and under no particular stimulation, one of two conclusions seems inevitable: Either the animal might have suffered pain in spite of the local anaesthetic, or it might not have felt the pain from the differential stimulation. The latter alternative seems the better one and would suggest that the operation raised the dog's threshold to differential pain stimuli.

(8) Under the condition of pain stimulation and slight wincing on the part of the dog there is evidence that the anterior concentration rises to a maximum far exceeding that under passivity to pain stimulation. As compared with the latter situation the distribution now spreads laterally and posteriorly, encompassing the auditory area. The posterior concentration is at a lower maximum but higher than under brightness stimulation with the dog passive. This observation, along with many others of a similar kind, points to the multiple functioning of given points on the cortex.

(9) In the stimulus-situation where leg movements occurred in response to artificial stimulation of the dog's legs, records are incomplete. However, the anterior pole exhibits a pattern similar to situation 3 where the dog was passive to artificial head movements, but exhibits a higher maximum when under artificial limb-stimulation. From these facts it can be concluded that the anterior maximum is conditioned both by sensory and motor modes of activity. A maximum appears which extends into the anterior ectolateral gyrus, which, under passive conditions, exhibited a minimum level. In this same region medium concentrations of energy were found under two other conditions, namely, wincing with pain stimulation and gross movement with pain stimulation. This suggests that the anterior ectolateral gyrus plays an important part in the voluntary initiation of movement along with activity nearer the extremes of the poles. Again, the indications are that the extreme visual pole is more active when the dog moves under no differential stimulation than when brightness stimulation is applied.

(10) Under conditions of gross movement to pain stimulation both poles appear maximum. The posterior concentrations extend from the posterior lateral gyrus to the sylvian region, taking in

the so-called auditory area. In this total action-pattern the auditory area seems to be an integral part of the posterior concentration; whereas in situation 11 this region becomes part of the anterior concentration. The pattern resulting from gross movements to pain stimulation suggests that visual activities are at a maximum when the dog is highly active and harmonizes with the thesis that more energy in this area is required for form discrimination than for mere brightness discrimination. When the dog is struggling to free himself from the apparatus in the presence of two or more experimenters it is safe to conclude that form discrimination approaches a maximum, even when illumination is poor.

(11) In situation 11 (gross movements to motion of the body) the posterior concentration seems greatly reduced, and the anterior pole raised to a maximum throughout, extending from the median line to the sylvian gyrus, thus including the auditory area. This pattern proves again that both the stimulus- and behavior-situations must be taken into consideration before a given pattern will become intelligible. Any effort to find a simple one-to-one correlation between behavior and stimulation situations separately is futile and misleading. In the present case, for example, when the dog was making gross responses to artificial movement of the body, the so-called auditory area of the cortex was highly active, yet there was no more auditory stimulation than in situations where concentration in the auditory area was at a minimum.

(12) In situation 14, where head movements were made to pain stimulation, both concentrations are reduced and the points of maxima are confined to the middle lateral region.

(13) Maximum concentration in the so-called visual area (posterior ectolateral and posterior lateral gyri) is found under the condition of gross movement to pain stimulation. Medium concentration is found when the dog is passive to artificial movement of the legs and when it is making less movement to motor stimulation; low degrees of concentration appear when the dog is passive to brightness stimulation, passive to no particular experimental stimulation, passive to pain stimulation and when making

head movements, only, to pain stimulation. In all of these situations visual stimulation has not been wholly eliminated; nevertheless, the fact remains that under gross movement to pain stimulation, there was more activity at the occipital pole than when the passive dog was deliberately subjected to brightness stimulation by a dazzling light.

(14) The so-called parietal region of the dog's cortex reveals no measurable concentration with the dog passive under brightness stimulation; some activity appears with the animal passive under artificial movement of the legs, and with the dog making slight leg movements to motor stimulation; moderate concentration occurs when the dog winces to pain stimulation; maximum concentration is shown when the dog is passive to movements of the head, and when it makes gross movements and head movements to pain stimulation.

(15) Within the limits of our records, the auditory area, so-called, shows slight activity with the dog passive to brightness stimulation, when the dog is passive to head movements, passive to limb movements, and when making head movements to pain stimulation. A high degree of concentration occurs in this region when the dog winces to pain stimulation and when it makes gross movements of the body to pain or to artificial movements of the body.

(16) The area to which tradition assigns facial and muzzle sensitivity in the dog shows slight concentration with the dog passive, and moderate activity under the condition of gross movements to pain stimulation. Maximum activity occurs with head movements to pain stimulation, wincing, and gross body movements to pain.

(17) The somaesthetic area reveals slight or moderate concentration with the dog passive to brightness stimulation, passive to leg movements, passive to pain, and gross movements to pain stimulation. This area exhibits maximum or nearly maximum concentration under the following conditions: passive to head movements, wincing to pain, gross movements to pain and to motion of the body.

(18) The median extremity of the supposed somaesthetic area,

said to be the seat of sensibility for the hind legs, shows slight disturbance with the dog passive to artificial movement of the limbs, moderate activity with the dog passive to brightness stimulation and with head movements to pain stimulation. Maximum concentration appears in this region with the dog passive to *head movements,* wincing to pain, when making gross movements to pain, when making gross movements to rolling of the body, and when artificial movements of the legs are produced. It is important that maximum concentration in this region not only may occur when the hind legs are being stimulated excessively by voluntary movements but also when the dog's head is moved and the animal is passive! This must mean that the total situation confronting the animal must be taken into account in understanding the activity of the cortex, for there is no reason to suppose that with the dog passive there should be excessive stimulation of the hind legs. This area obviously has more than one function and what it shall be depends upon a total situation.

(19) The so-called motor area of the dog's cortex exhibits moderate concentration in the majority of situations in which the dog is supposedly passive. The lateral region of this area, often associated with head movements, shows slightly increased activity under brightness stimulation. All records from this area reveal maximum activity when the dog is making gross movements. Curiously, it exhibits nearly maximum activity with the dog passive to motor stimulation of both the head and legs, and less activity when the dog was wincing slightly to pain stimulation from the tail.

(20) These results support older findings in a general way in so far as specific areas are involved in the reception of stimuli and in the initiation of movement. However, the results demand a different interpretation, namely, that the activity of a specific area depends not only upon the proximity of the area in question to the incoming and outgoing nerve roots but also upon the amount of energy necessary to execute a given performance. With gross and intensive activity, higher energy concentrations extend over larger areas of the cortex, obviously a requisite for the initiation of the more vigorous movements. At the same time,

the presumption is that all of the cortex is involved at all times in whatever activity the animal is pursuing. The significance of activity at any one point of the cortex, then, can be understood only in terms of the laws of dynamics and not by recourse to purely anatomical structure.

(21) It is quite evident that level and extent of the energy concentrations are not independent or separate factors in brain economy. Whenever a given performance requires increased vigor of action a more complex and widespread concentration is required. This is especially obvious in the extension of maxima to the so-called auditory area regardless of whether auditory stimulation changed or not.

(22) It seems beyond doubt that a given area of the cortex may play a multitude of rôles in accordance with the character of the total cortical pattern, that is, in accordance with what is happening in other parts of the cortex. Physiology must abandon, therefore, any theory of cortical activity that rests upon localization of function. It is no more legitimate to speak of localization of function in the cortex than it is to speak of the localization of weight in a stone. The weight is a function not of the stone as an isolated thing but of the position it occupies in a gravitational field, together with its density. Likewise, a given area of the cortex plays a certain part in the economy of the total nervous system in virtue of its position in the system, namely, its anatomical proximity to the receptors of the body and to other specific parts of the cortex. This specificity of function is a matter of dynamic relation, not a property inherent in the structure of the part. This is in no sense localization of function, because the function depends upon the entire system. To destroy a part, therefore, and to find a loss in function as a result means that the capacity of the total system to condition that particular performance has been lost, because of the destruction of vital parts. The loss must be explained by the fact that the organization to continue the function no longer exists. In this connection, we have pointed out that a more complex function, as, for example in form vision *versus* brightness vision, is destroyed, by a loss of a proportionately lesser amount of energy. This energy is found

in the visual area not because this area has a visual function and other areas do not but because the total cortical pattern responsible for vision is more highly differentiated in the visual than any other area in terms of the greater amount of incoming energy in that area than at any other point.

(23) It seems necessary to abandon a distinction between sensory and motor functions. The anatomical point of view of studying the position of parts and direction of conduction has led to errors of interpretation. In place of this view, we must consider the consciousness of the organism to depend upon the neural field as a whole. It is not referable to incoming any more than to outgoing impulses or to 'sensory' any more than to 'motor' impulses. In fact, these terms have significance only in an anatomical sense. This conclusion is demanded by the facts as well as by logical considerations. Heightened activity in the so-called sensory areas is quite as likely to appear without increased peripheral stimulation as with it. In like fashion heightened activity in the so-called motor areas is as likely to appear without movement as with it, under the right conditions, as when the main consequence of cortical activity is the perception of movement, intense sensory stimulation, and form.

(24) In accordance with the facts and suggestions that have preceded, a field theory of the nervous system is demanded if its activities are to become intelligible. A field theory supposes: (1) that the nervous system always functions as a whole, (2) that the activity of any part depends upon the activity of the whole, (3) that the activity of the part is not fixed alone by its internal structure or by its position with respect to the periphery, but by a vast number of dynamic relations within the total field, (4) that the activities of any part of the cortex come about through processes of growth and differentiation which determine the functioning of the sense organs as well as the functioning of the cortex, (5) that any mechanical, mosaic, or synthetic theory of nervous activity is futile, neither fitting the facts nor resting upon sound logic, (6) that the concept of reflex action must be supplanted by the concept of configurational response, (7) that

further progress in research upon the nervous system, if adequate, must be undertaken in the light of field hypotheses.

(25) The results of this investigation, although of a preliminary character, are those which a general field theory of cortical activity would predict. They are construed, therefore, as supporting a general field theory. The results do not justify making more precise statements concerning the details of gradient activity, but obviously support the concept in a general way. This, it is presumed, is the history of every theory. Its beginning must be general and merely suggestive, and is so presented here. The next step is, by a refinement of technique and control of the animal, to test possible differentiations of the suggestion herein pointed out.

(26) The results of this investigation are in harmony with the major findings of Lashley, Dusser de Barenne, Magnus, Coghill (24) and others in so far as they point to a field theory of cortical functions.

(27) The specific contributions of this investigation are: (1) a fairly clear-cut demonstration by the action current technique of the 'fluid'-and-field-character of the dog's cortex, (2) the discovery of a bi-polarity in the cortical field in which the anterior and posterior poles dominate the total pattern, (3) the conclusion, based on various suggestive data that the distinction between motor, sensory, and association areas is false.

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A STUDY OF SUCCESSIVE DISCRIMINATIONS OF BRIGHTNESS IN CHICKS[1]

by

MARGERY G. CUTSFORTH

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I. INTRODUCTION

It has been amply demonstrated that chicks can perceive constant relationships in changing situations, relative brightnesses of lights when absolute brightnesses are varied, constant relationships of size when the actual sizes of objects in the situation are changed, or the objects themselves are of different nature in the altered situations, and within limits, relations of forms. We are justified, then, in assuming that the behavior of chicks displays insight in situations simple enough to allow for rather definite, constant relationships in a situation which is itself 'meaningful',

[1] Submitted to the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

that is, which constitutes in its entirety the process of reaching a goal.

In work of this sort done with chicks, the constant factors of the situations presented have been confined largely to simple, spatial arrangements. The question arises as to how far similar insightful behavior may be demonstrated in more complex spatial situations which involve a temporal factor, that is, in which the total situation is so arranged that a succession of problems present themselves, not only in a constant relationship to a spatial situation, but also in a fixed, successive relationship to one another.

In pursuit of this problem, a situation was so arranged that, in order to reach a goal of food and companionship, chicks must make three successive choices of brightnesses. The three choice-situations involved were constant in general spatial arrangement and also in the actual brightnesses of the three lights used in each. The problem, therefore, is to discover whether the chicks can learn at the same time to select the correct brightnesses in their successive order, and to disregard exactly the same absolute brightnesses when they appear outside the preferred succession.

By varying the method of introducing the complications of the problem, an effort was made to discover whether more efficient learning occurred when the entire situation was presented at the beginning of the experiment, or when new problems were presented successively as the preceding ones were learned.

II. Apparatus

1. Description. The apparatus consisted of a multiple choice box (Fig. 1), 72 inches long, 10 inches high, and 24½ inches wide, mounted on legs to a height of 26 inches from the floor. The box was painted a dull black inside and outside, and the floor was closely covered with dull black oil-cloth. In the middle of the front end-board was an aperture 6½ inches wide by 7 inches high, the lower edge of which was flush with the floor. This aperture was covered by a wooden door (A), hinged at the bottom, which, when open, formed a straight angle continuation of the floor. In the rear 18-inch section of the box, the floor descended at an angle of thirty degrees, and was covered with

½-inch mesh hardware cloth. It opened out through an 8½-inch space into a feeding box, 40 inches long and 29 inches wide, constructed of slats and ½-inch mesh chicken netting.

The length of the box could be divided into four compartments by means of three removable partitions, each of which consisted

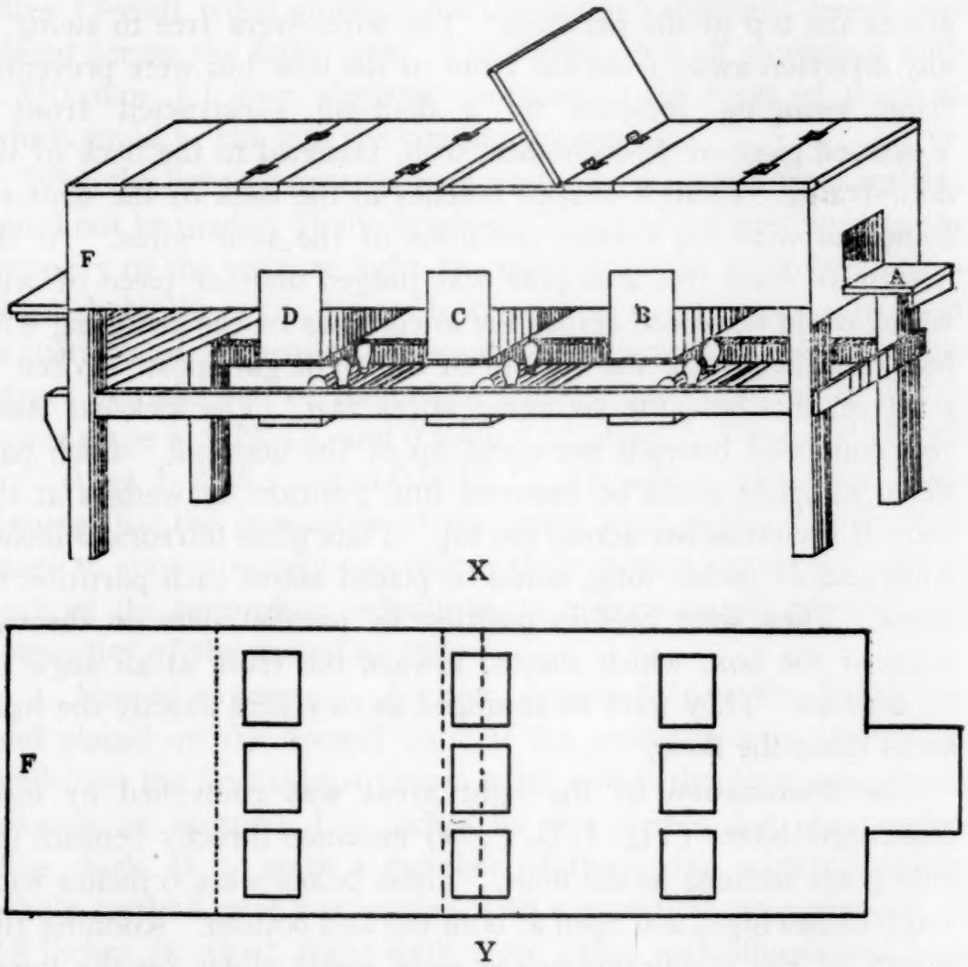

FIG. 1. X. Diagram of Chick Apparatus Showing Wooden Door (A) and Light Diaphragm-Boxes (B, C, D); Y. Top View of Apparatus.

of three adjustable gates, 6 inches wide, separated from one another by 2-inch strips of board. Light apertures were arranged in the floor by means of milk glass sections, 6 inches wide and extending across the width of the box. They were placed twelve inches from the front of the box, and at 12-inch intervals from one another. The partitions were placed directly behind

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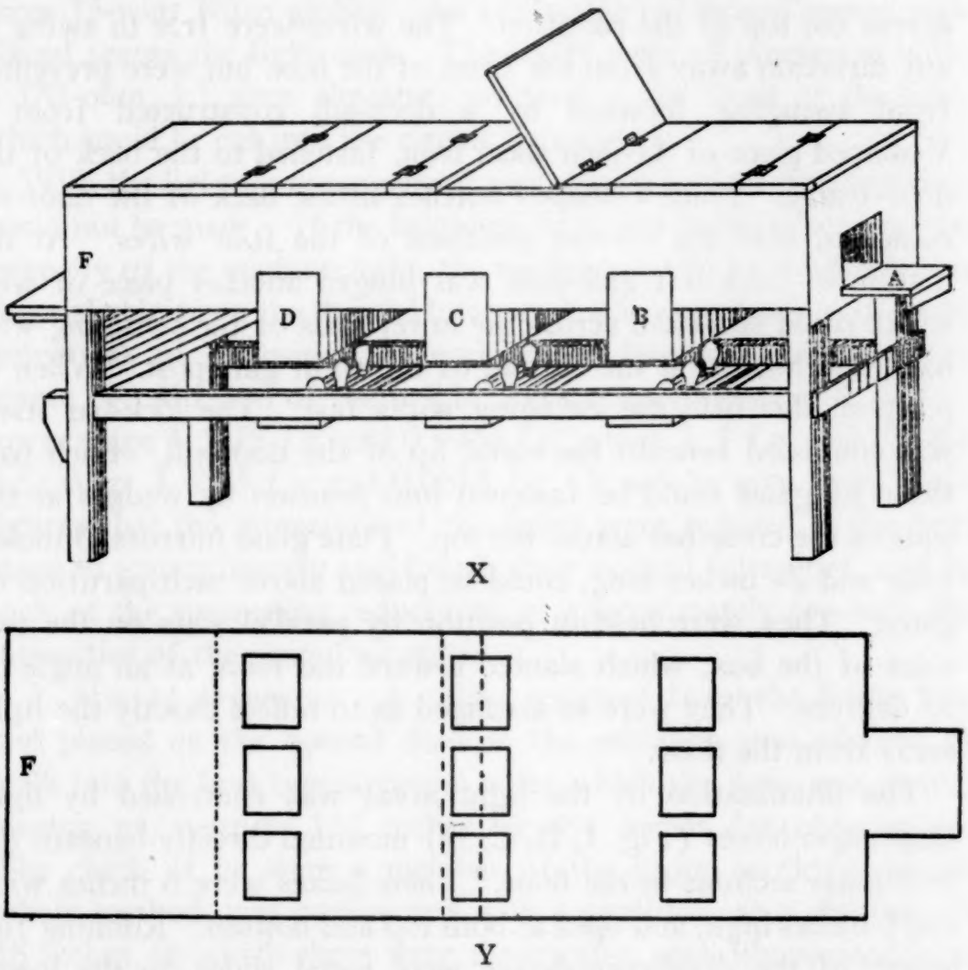

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the apertures and each gate was illuminated by the light admitted through an opening in the oil-cloth floor-covering. These openings were 4 inches wide and 6 inches long, the length of the opening coinciding with the width of the gate. Each gate was constructed of four pieces of number 12 galvanized wire, 7½ inches long, swung by means of screw-eyes from a transverse bar across the top of the partition. The wires were free to swing in any direction away from the front of the box, but were prevented from swinging forward by a door-sill constructed from a V-shaped piece of ¾-inch sheet iron, fastened to the back of the door-frame. Four V-shaped notches in the back of the door-sill coincided with the correct positions of the four wires. At the bottom of each left gate-post was hinged another piece of wire which could be placed across the lower ends of the swinging wire bars, and hooked at the bottom of the right gate-post. When in position, this held the swinging wires fast. The lock-bar itself was concealed beneath the metal lip of the door-sill. Each partition of gates could be fastened into position by wedges at the ends of the cross-bar across the top. Plate glass mirrors, 3 inches wide and 24 inches long, could be placed above each partition of gates. They were held in position by parallel slats on the two sides of the box, which slanted toward the front at an angle of 35 degrees. They were so arranged as to reflect exactly the light areas from the floor.

The illumination of the light areas was controlled by light diaphragm-boxes (Fig. 1, B, C, D) mounted directly beneath the milk-glass sections in the floor. These boxes were 6 inches wide and 6 inches high, and open at both top and bottom. Running full length of the diaphragm-boxes were metal slides on the lower edges, in which was fitted a second milk-glass filter, illuminated from below by three 50-watt Nilco globes. The brightness of the areas on the floor was controlled by press-board slides which could be slipped into position over the milk-glass plate. There were three apertures in each slide, corresponding in position with the three light areas. The largest aperture was a square, 8½ centimeters on a side, the second a circle with a diameter of 1 centimeter, and the third a pin hole, 1 millimeter in diameter.

The apparent brightness of the brightest area, as measured by the Macbeth illuminometer was 27.6 f.c. The brightness of the medium area was 0.515 f.c., and the dimmest light was merely a glow, below the threshold of the illuminometer.

At the rear of the box, a 4-inch milk-glass section, flush with the floor, extended across the width of the box, illuminated by three 15-watt Nilco globes. An adjustable cardboard screen was placed across the light area. The lights were all connected with a 370 ohm, 1.1 amp. rheostat, mounted at the front of the box, which could be cut into the circuit by a switch.

With the lighting arrangement as it was, a perfect transposition could not be made. If the brightest light had been reduced to the intensity of the medium light, the medium would have been indistinguishable from the dim. However, trials were made with three reductions of intensities. Illuminometer readings for the three stages of reduction of the bright and medium lights were as follows: stage 1, 9.78 f.c. and 0.1970 f.c.; stage 2, 5 f.c. and 0.1062 f.c.; stage 3, 2.95 f.c. and 0.0618 f.c. It will be seen from these figures that the intensities of the lights were reduced at the first stage to approximately one-fourth their normal intensities, and in each of the succeeding reductions, to approximately one-half the intensities of the preceding stage.

2. *Use of apparatus.* A chick, removed from the living box and placed on the opened door at the entrance, was allowed to walk into the first compartment, after which the door was closed, leaving an aperture 1½ inches by 6½ inches for observation. The chick, if he were a member of the group working on the whole method, was confronted with a partition, at a distance of 18 inches, in which there were three gates, each illuminated by a light area at its base, which was reproduced in the mirror above the gate. The wires of the dimly illuminated gate were free while the wires of the other two were fastened. There was nothing in the appearance of the three gates to indicate which was the unlocked one. After the chick had passed this partition, by pushing against the wires so that they swung out and allowed it to go through, it was confronted with a second, identically the same, except for the position of relative intensities in the light areas,

and for the fact that the free gate was the one of medium illumination. The third compartment was identical with the other two, except again for the difference in arrangement of brightnesses, and for the fact that the brightly lighted gate was free. On going through the last gate, the chick stepped out upon an inclined runway leading into the feeding box attached to the choice box, where it got its daily feeding in company with the other chicks. As it went down this runway, it passed under another dimly lighted area on the level of the floor, an inch in height and extending the width of the box. This, together with the daylight admitted where the choice box and the feeding box joined, served as a means to make the path more definite by increased illumination beyond the end of it. The next time the chick entered the box, its arrangement would be the same except for the positions of the different brightnesses in the light areas, and the corresponding positions of the free gates. These conditions were changed between trials.

III. Description of the Experiments

1. The chicks. Twenty-two pure-bred white leghorn chicks were used in the experiments. They were purchased from a hatchery when one day old, were all subjected to similar conditions of living and feeding, and, when the training began, were all given the same number of trials each day, under as nearly uniform conditions as possible.

2. The experimental groups. The chicks were divided into three groups, each trained by a different method.

Group I. The whole method. Seven chicks, four males and three females, were trained from the first with all three partitions in their places in the apparatus. They were thus confronted with the problem of learning as a whole the successive relationships involved in the series of differentially lighted unlocked gates.

Group II. The serial method. Each of the three males and four females in this group were at first placed in the apparatus with only the rear partition in place. Their problem was to choose the brightly lighted gate in whatever position it might appear relative to the other two gates. As soon as this discrimination

was established, to the point of nine correct choices out of ten, the middle partition was added. In this partition the free gate was the one lighted with medium brightness. The third partition, in which the dimly lighted gate was the correct choice, was added after nine of ten correct responses had been made in the complete situation which the partial series presented. The light areas not in use were covered by strips of black cardboard.

Group III. The test method. For the three males and five females of this group, all the partitions were put in place, but only the front (dim) and the middle (medium) were illuminated. The rear partition was left unlighted, and a strip of black cardboard was slipped under the floor covering so that it concealed the light areas ordinarily exposed by the holes in the floor covering. To keep the chicks from establishing some particular route through this compartment, only one gate was left unfastened, the one which was illuminated brightly in the same arrangement for the other two groups. The wires of this gate were drawn across and fastened to the back of the frame from which the wires were hung. As soon as nine or ten perfect runs had been made with this arrangement, all the gates were unlocked, the light areas illuminated as for the same arrangement for the other groups, and a record kept of the path each chick took through this compartment.

3. Number and arrangement of trials. Work was begun when the chicks were thirteen days old. For the first three days, modified trials were given to accustom them to the apparatus and to finding their food at the end of the choice box. From this time on, training continued for one hundred eighty-five trials, covering fifty-six days. The experimenting was done from eight-thirty to about eleven each morning, and in the evening beginning at four-thirty. On typical days, four trials were given, divided evenly between the morning and the afternoon periods.

4. Records. Time and error records were kept for each trial. A drawing was made of the path which each chick took from the start to the feeding box, showing the number, order and location of errors. An error was counted each time a chick pushed his head between the wires of a gate, or otherwise attacked it with

sufficient force to have enabled him to go through had the gate been free. Light touches or pecks at the wires, probably uncertain tendencies toward the gate, or aspects of exploratory behavior, were not counted as errors. Qualitative records of the chicks' behavior were also made whenever it seemed to warrant special note.

IV. Results

1. Chicks can perceive successive relationships. The fourteen chicks of groups I and II were observed throughout the course of one hundred eighty-five trials in a situation requiring for its correct solution the perception of a series of three mutually related arrangements of brightnesses. Of the fourteen chicks, eleven, or 78.6 per cent, had learned the procedure, judged by a standard of nine of ten correct, complete responses at the close of the experimental period.

Of the eight chicks of group II for whom the learning problem consisted of a series of two successive choices, all of the six chicks whose trials were continued to the end of the series learned the problem.

2. There is no substantial difference in the efficiency with which groups I and II learned the problem. Of the three chicks which failed to complete the problem at the end of the experimental series, two belonged to group I and one to group II. On the face of it, this appears to show a superiority of the serial as compared with the whole method. However, the individual differences which will be indicated later between the performances of different chicks within the same group, and the remarkable similarities which will be shown to obtain between the two groups, make it seem doubtful whether this is a valid measure of comparison. Furthermore, the only unhealthy chick of the fourteen was included in group I, and was one of those which failed to complete the learning.

Fig. 2, A and B represent graphically the course of the learning of all seven chicks of group I combined, in terms, respectively, of errors made and per cent of right trials for each group of five trials. The two graphs present further an analysis of each of the

main curves, showing the errors and the per cents right for each brightness value. Thus, the main error curve shows the sum of the errors represented in the other three curves at each interval, while the success curve represents what we might term the synchronizing of successful choices, a right trial in the main curve representing three right trials in the subsidiary curves only when they occurred in the relations to one another specified by the conditions of the problem. This explains the fact that, whereas the

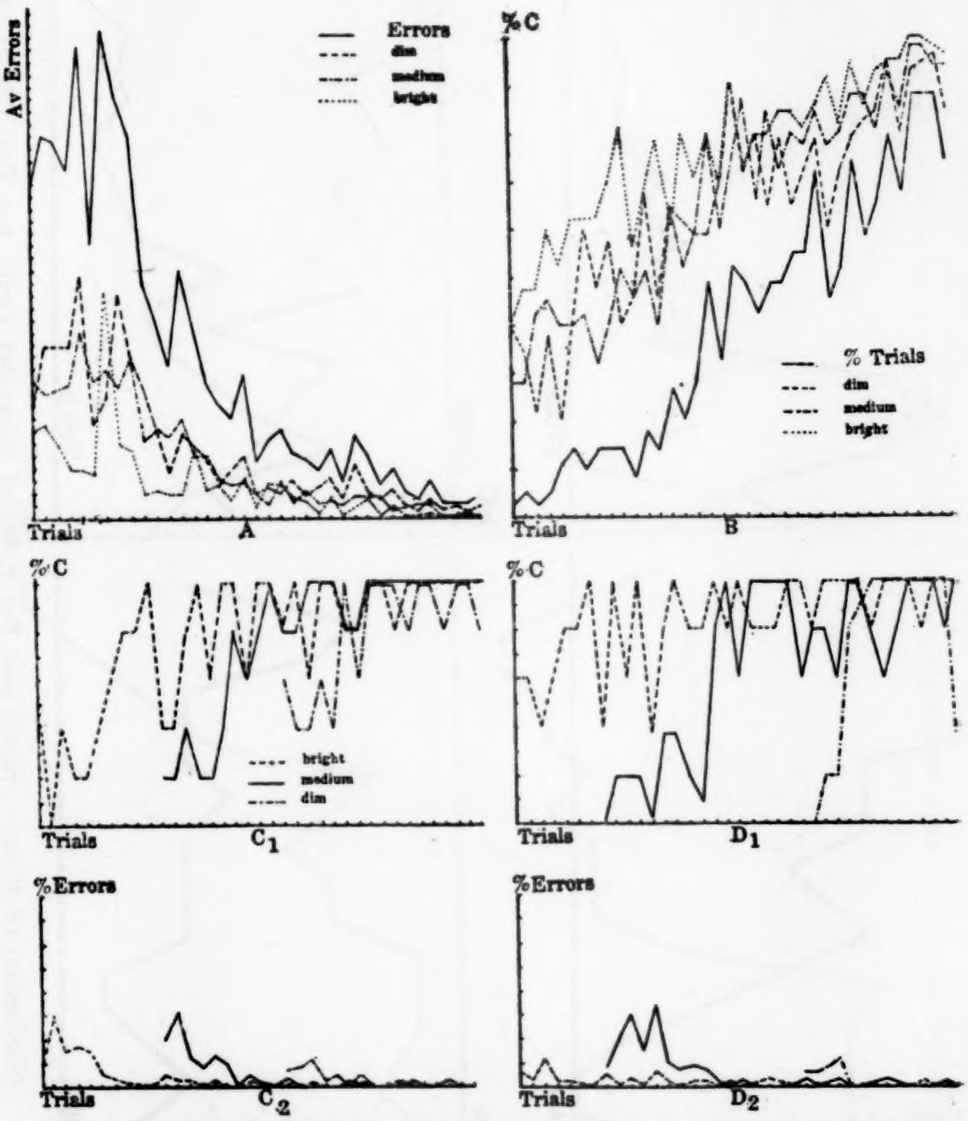

FIG. 2. A. The Distribution of Average Errors for the Chicks of Group I in Intervals of 5 Trials; B. Distribution of Right Trials; C_1 Per Cent Success for each 5 Trials (16); C_2 Per Cent Errors for each 5 Trials (16); D_1 Per Cent Success for each 5 Trials (17); D_2 Per Cent Errors (17).

four curves of Figs. 3 and 4 maintain a constant relation to one another throughout the diagram, the curve of completely successful trials tends to approach more nearly the course of the subsidiary curves as the number of trials increases.

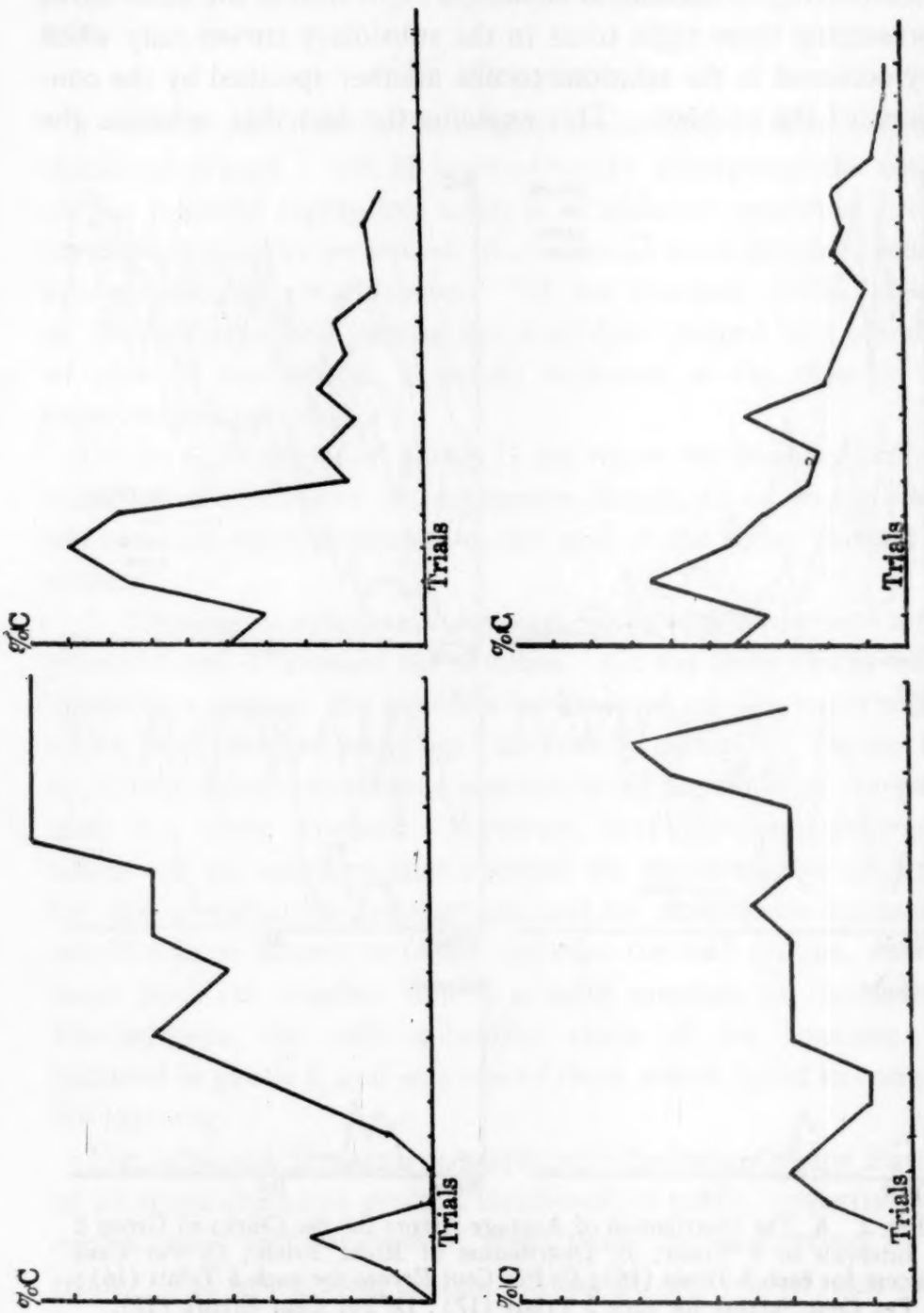

FIG. 3. Distribution of Errors (right) and Per Cents of Successes (left) for Two Chicks of Group I. C=Correct.

It will be seen from curve A that the rapid rise of errors in the fourth and fifth intervals is not accompanied by a corresponding decrease in per cents of success, but, on the contrary, the success curve continues its steady rise, which reaches its peak at

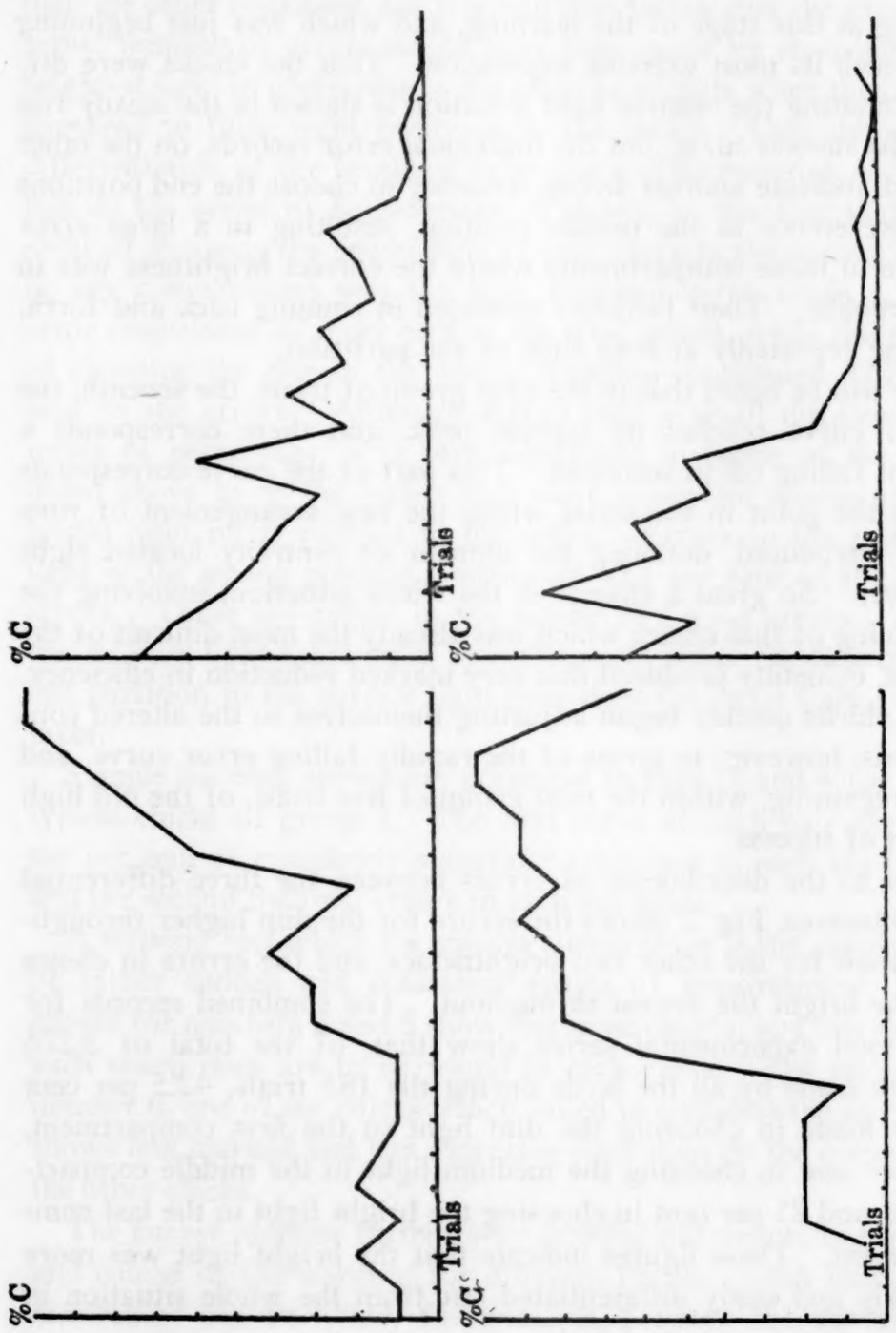

FIG. 4. Distribution of Errors (right) and Per Cents of Successes (left) for Two Chicks of Group I. C=Correct.

the sixth group, where the error curve takes such a steep decline that it would lead one to expect a spurt of success instead of the continuation of the same slow increase. As a matter of fact, the error curve discloses a condition that the curve of right trials does not disclose, that is, the conflict of methods which the chicks were using at this stage of the learning, and which was just beginning to reach its most extreme expression. That the chicks were differentiating the relative light situation is shown in the steady rise of the success curve, but the individual error records, on the other hand, indicate another strong tendency to choose the end positions in preference to the middle position, resulting in a large error score in those compartments where the correct brightness was in the middle. Their behavior consisted in running back and forth, trying repeatedly at both ends of the partition.

It will be noted that in the next group of trials, the seventh, the error curve reaches its highest peak, and there corresponds a slight falling off in successes. This part of the curve corresponds with the point in the series where the new arrangement of runs was introduced, doubling the number of centrally located right choices. So great a change in the whole situation, involving the doubling of that choice which was already the most difficult of the three, evidently produced this very marked reduction in efficiency. The chicks quickly began adjusting themselves to the altered conditions, however, in terms of the rapidly falling error curve, and the regaining, within the next group of five trials, of the old high point of success.

As to the distribution of errors between the three differential brightnesses, Fig. 2 shows the errors for the dim higher throughout than for the other two brightnesses, and the errors in choice of the bright the fewest throughout. The combined records for the total experimental series show that, of the total of 3,276 errors made by all the birds during the 185 trials, 42.5 per cent were made in choosing the dim light in the first compartment, 36 per cent in choosing the medium light in the middle compartment, and 21 per cent in choosing the bright light in the last compartment. These figures indicate that the bright light was more quickly and easily differentiated out from the whole situation in

terms of its own position in the series than were the other two lights. If it indicated a preferential learning of the bright-response as a unitary, absolute brightness response, not only would the correct brightness response have been made with fewer errors than the other responses, but it would also follow that the greatest actual number of errors would have been made by choosing the brightest light in preference to the other two lights when the latter appeared in their right positions in the series. That the early differentiation of the brightest light was a differentiation in relation to the series of brightnesses, is shown by the fact that the error of choosing the bright light in preference to the correct light in any compartment was the least frequent error made. This error constituted 27.2 per cent of the total errors, while the error of choosing the dim in the wrong situation constituted 32.7 per cent of the errors. Although this is only a small difference in terms of percentage, it is very significant in terms of the fact noted above as to the earlier and more consistent choice of the bright light in its relation to the series. Errors to the medium light in the wrong position constituted 40.1 per cent of the total errors. These are rather in the nature of 'good errors', since the medium light bears more resemblance in either the first or the last partition to the correct light than does the other light of the three.

Sample learning curves are presented in Figs. 3 and 4 for four typical chicks of group I. The first curve of each pair presents the per cent of completely successful responses in each ten trials, and the second the total errors in each ten trials.

A striking fact which the success curves show is the appearance of rather sudden and consistent spurts of improvement. The curves for numbers 3 and 5 show this most clearly, and one or two such sharp rises are to be found in each curve. The curve for number 6, one of the chicks which failed to complete the learning, shows less marked and less extensive rises than do the curves for the other chicks.

The curves indicate further very striking differences in the rate and course of the learning for different chicks. Such individual differences can be noted, for example, between the curves for

numbers 1 and 5, both of which completed the problem. Individual differences in speed of learning and efficiency of performance are indicated in Table II, which shows the number of trials each chick made in the series after having reached the standard of nine correct runs out of ten. Disregarding the last ten trials in which the light intensities were changed, chick number 2 made one trial, a correct one, after having reached the standard. Chick number 1 made 14 trials, 11 or 78 per cent correct; number 5, 29 trials, all correct; number 4, 47 trials, 38 or 80.8 per cent correct; and number 3, 62 trials, 57 or 91.1 per cent correct.

Fig. 2, C and D present typical success and error curves for chicks of group II. The same sort of variability between chicks in rate of learning is shown in this group as in group I. In learning to choose the bright light when only one partition was in place, the arbitrary standard was reached at the nineteenth trial by the fastest chick, and at the fifty-second by the two slowest; in learning to choose the medium and the bright when two partitions were in place, the final trial of standard performance ranged from the sixty-fifth to the one hundred eleventh; for the final standard of choosing the dim, the medium and the bright in their serial relations when all the partitions were in place, from the one hundred fifth to the one hundred fifty-third trial.

To avoid confusing terms, the problem as originally presented, involving the choice of only the brightly lighted gate, will be referred to as *B*, the second complication involving the successive choices of the medium and the bright will be termed *M-B*, and the final complication, *D-M-B*.

The outstanding fact presented by these graphs is the effect upon the already learned response of the addition of new complications. In every case except one, the per cent of right trials in *B* falls below its initial level with the alteration of the problem to *M-B*. Inspection of the curves will show that a similar but much less extensive effect was produced with the introduction of *D*. Table I shows, for each chick, the influence on the total response of the introduction of each new complication. Errors, average time and number of right trials are compared for the first

ten trials of *B*, the last ten trials of *B*, the first ten trials of *M-B*, the last ten trials of *M-B*, and the first ten trials of *D-M-B*.

With the introduction of the medium brightness choice in the second partition, the possible number of errors increased; the time for each trial might be expected to increase with the addition of another obstruction in the path to the food box, and the chance for completely successful trials is reduced further by the necessity of " synchronizing " right choices in the two situations. Further, the successive factor is introduced here for the first time. Table I shows, as might be expected, higher error scores, longer average time (except in two cases in which the initial time score in *B* was exceptionally high) and fewer complete right trials in the first ten trials of *M-B* than in the first ten trials of *B*.

TABLE I

Responses of chicks (group II) before and after introduction of new complications

	B: first ten trials	B: last ten trials	M–B: first ten trials	M–B: last ten trials	D–M–B: first ten trials
Chick 16					
Total errors	38	1	63	1	15
Average time	232.4	8.8	72.7	27.9	49.4
Errorless trials	3	9	1	9	3
Chick 17					
Total errors	8	3	58	0	23
Average time	16.2	8	129.5	15.7	55.4
Errorless trials	6	7	1	10	1
Chick 18					
Total errors	19	1	47	1	17
Average time	21.9	16.5	149.2	39.5	54.3
Errorless trials	6	9	2	9	6
Chick 19					
Total errors	15	1	49	23	23
Average time	21.9	7.4	101.1	29.5	46.3
Errorless trials	5	9	1	9	4
Chick 20					
Total errors	12	4	49	8	26
Average time	14.9	9.3	131.2	12.8	27.5
Errorless trials	6	7	1	5	3
Chick 21					
Total errors	31	1	35	1	23
Average time	77.9	9.6	57.5	44.9	65.9
Errorless trials	6	9	2	8	3
Chick 22					
Total errors	11	1	20	2	55
Average time	44.8	22.4	47	34.1	108.5
Errorless trials	6	9	3	9	3

Based upon the same argument, a similar reduction of efficiency should be shown with the introduction of the third partition, which likewise increased possibilities of high time and error scores and added a further complication to the brightness succession. The remarkable thing brought out by Table I is that all three of the measures, instead of showing the expected decrease of efficiency, show an actual increase of efficiency over that shown with the introduction of the second partition. On the whole, then, the introduction of the last complication caused less disturbance of the learned serial response than did the introduction of the serial situation in a simple spatial pattern. This fact argues for a transfer of the successive principle to the new situation created by a new step in the series.

Further comparisons between groups I and II may be drawn from the data of Table II. The most obvious comparison of the complete performance in the two groups is that based upon the number of times the stimulus situation was repeated before the complete, correct response was developed to a determined standard of efficiency. The second column of Table II shows that the completion of the learning for the five chicks of group I which finished the problem ranged from the 116th to the 180th trial, with an average of 149.4 trials. For the six chicks of group II

TABLE II

Summary of general data for groups I and II

Chick number	No. trials to learn	No. errors per choice	Ave. time per choice	Per cent right post-standard
		(Group I)		
1	167	0.946	16.8	78.6
2	180	1.02	14.1	100.0
3	116	0.77	15.3	91.9
4	152	0.80	20.1	100.0
6	(not finished)	0.829	14	
7	" "	0.799	16.7	
Ave.	149.4	0.845	17.2	
		(Group II)		
16	150	0.589	22.1	90.0
17	150	0.593	19.1	80.6
18	138	0.51	18.8	90.5
19	105	0.497	13.9	83.2
20	(not finished)	0.949	14.3	
21	147	0.572	23.7	91.2
22	153	0.66	20.4	88.0
Ave.	140.5	0.634	18.8	

to complete the learning, the last trials of standard performance range from 105 to 154, averaging 140.5. Thus, both as to average and range, group II shows a slight superiority over group I.

The second objective measure of comparison is average number of errors for each choice made. The actual number of possible right choices for chicks of group I was 555 in the 185 trials of the series. In group II, the number of possible right choices for any given chick depended upon the rapidity with which it completed each part of the learning. The actual number of possible right choices for the individual chicks ranged from 361 to 449. Basing the average errors per choice upon the actual number of possible right choices for each chick, group II again shows a slight advantage over group I, with an average error score of 0.634 for all seven chicks as compared with 0.845 for all seven of group I. The range for group II is from 0.497 to 0.949, while for group I, it is from 0.80 to 1.02. The average time per choice for the two groups is almost identical, with only a slight superiority for group I, 17.2 seconds as compared with 18.8 for group II. The ranges are almost identical, 14 seconds to 23.2 seconds for group I, 13.9 seconds to 23.7 seconds for group II. The last column of Table II shows the per cent of right trials for each chick during the continuation of the experiment after the arbitrary standard of completion had been reached. The three highest scores, 100 per cent for number 5 and for number 2 (only one trial), and 91.9 per cent for number 3, and also the lowest score, 78.6 per cent for number 1, belong to group I. With the exception of the high score for number 5, the range for group II is practically the same. This indicates practically no difference in the efficiency of continued performance for the two groups.

It is quite possible that a large share of whatever superiority these objective measures indicate can as well be attributed to the processes of increasing maturity in the chicks as to the methods employed in the two phases of the problem. The very young chicks in the early part of the experiment were more highly active than they were at later stages of their growth. Their movements were quicker and more headlong. They often rushed at the

locked gates and threw themselves against them with enough force almost to upset themselves, while, as they grew older, their whole rate of movement, both outside as well as within the experimental situation, was appreciably slowed up, at any rate in proportion to their size of body. They became less precipitate, and were more cautious in making attempts at the gates. Since the chicks of group II were presented with a much simpler problem during this early period, the alteration in their own normal form of behavior was to their advantage by the time the new complications were added to the problem. Furthermore, their initial adaptation to the general nature of the experimental situation was made under simpler and less confusing circumstances. A further incidental factor may also have been effective in this situation, in that the distraction of the mirrors which had been removed well before any of the chicks of group II had reached the complete complication of the problem, was an influence in every one of the three choices of the chicks of group I from the start.

The facts presented in discussion of the performance of group II indicate that there is less essential difference between the whole method and the serial method as used in these experiments than the names imply. It will be recalled that the performance of group II did not consist in the learning of one part, followed simply by the learning of another part of the problem. The introduction of each new complication practically constituted an entirely new problem, in which the previously learned parts took on new relationships, a process which involved a temporary decrease in the efficiency of the response to the formerly learned processes themselves. Just as the efficiency of the chicks of group I increased with repetition of the stimulus-pattern, so the efficiency of the chicks of group II increased in meeting the new, but related problem of the introduction of the third brightness situation as compared with the introduction of the second.

3. Alterations made in the actual intensities of brightness indicate that the responses of the chicks were in terms of brightness relations rather than of absolute brightness. It seemed of considerable importance to discover whether the choices of successive

brightnesses were based upon a perception of absolute brightness or whether they were characterized by a discrimination of relations existing among the three brightnesses and in respect to one another in the perceptual field constituted by the total situation of the differentially lighted partition. To this end, the last ten trials of the series were made with the absolute intensities of the lights altered to the degrees described before: II, 1. The first five trials of this series were made with the lights at the first degree of reduction. In the last five trials, the variations were as follows: second degree, third degree, normal, first degree, second degree. The conditions of the experiment did not permit of alteration in the direction of increased brightness. As a further check, however, a trial at normal illumination was inserted in the series of reduced illuminations. If the original learning had been based upon absolute brightness, this presentation of the learned situation should have brought forth as accurate response in the chicks as it did in earlier trials. In the combined responses of the fourteen chicks for the first five trials of reduced illumination, 88 per cent of the responses were correct, exactly the same proportion of successful responses made in the preceding five trials under normal illumination. Three chicks, numbers 1, 5 and 19, made no errors in the ten trials of altered illumination. Table III shows

TABLE III

Per cent of success for each chick, last ten trials of normal illumination, and ten trials of reduced illumination

		Normal light		Reduced light	
Group	Chick No.	34th group	35th group	36th group	37th group
I	1	100	80	100	100
	2	80	100	100	60
	3	100	100	100	60
	4	100	90	100	90
	5	100	100	100	100
	6	80	60	80	40
	7	60	100	40	60
II	16	60	100	100	80
	17	80	100	80	40
	18	80	80	80	80
	19	75	80	100	100
	20	40	40	60	40
	21	100	100	100	80
	22	80	100	100	60

the per cent of success for each bird in each five trial group during the altered illumination, and for the two groups of five trials preceding alteration of the lights. Inspection of the table shows little difference in the actual performance of the chicks in the first five trials of altered illumination from the average of the two preceding groups of trials. A rather marked reduction of success appears in the last group of five, however. Table IV gives the distribution of errors for each bird by trials in this group. This table shows that five different birds of the fourteen made errors in the situation involving the first stage of reduction, that an average of four birds made errors in the two presentations of the second stage, that five birds made errors in the third stage of reduction, and that three birds made errors in the normal illumination.

That the situation of reduced illumination constituted a relational situation for the chicks is shown by the fact that three of the birds, numbers 1, 5 and 19, made perfect scores on all the five trials of the final group, and that, of the birds making errors, there were four, numbers 4, 16, 18 and 21, that made perfect performances in all but one of the five trials. A further interesting fact is that of all the trials involving errors, only two were completely unsuccessful trials, that is, in only these two trials, made by the same bird, number 20 (a chick which did not complete the learning), were three wrong choices made in one run.

TABLE IV

Number of errors made by each chick in each of the last five trials of reduced illumination

Group	Chick No.	Second stage	Third stage	Normal	First stage	Second stage
I	1	0	0	0	0	0
	2	0	2	0	0	1
	3	0	1	0	1	0
	4	1	0	0	0	0
	5	0	0	0	0	0
	6	1	0	2	2	0
	7	1	0	0	0	1
II	16	0	1	0	0	0
	17	1	2	1	0	0
	18	0	0	0	1	0
	19	0	0	0	0	0
	20	5	0	3	1	0
	21	1	0	0	0	0
	22	0	1	0	1	0

All the other imperfect trials included errors in only one of the choices.

If the absolute brightnesses of the original lights were the stimuli to which the chicks had responded at first, the response to them should not, theoretically, have been confused by using them with a few variables. However, we find that three birds made errors in the trial of this group which involved normal lighting, whereas, in the last preceding group of five normal trials, the average number of birds making errors was 1.2.

From all the points of view considered, then, per cent of success, for the group, actual perfect responses made in the altered situations, the limited scope of errors in the imperfect trials, and the fact that the transposition effect was almost as great in the responses to the normal illumination when introduced in the altered series, as upon the altered brightnesses themselves, we are justified in concluding that the response of the chicks to each choice situation was an affair of relationships among the brightnesses rather than one involving choice of a series of absolute brightnesses out of repeated absolute-brightness situations.

4. Chicks of the test group developed consistent responses in a constant spatial situation. Six chicks of group III completed the problem involving two successive choices, the number of trials required for learning ranging from 100 to 162. The two chicks which had not completed the learning at the 162nd trial were dropped. After the problem involving two choices had been learned, the third partition was lighted as for the other groups, the gates were all unlocked, and the behavior of the chicks at the third partition was observed throughout the remaining trials. Table V shows the number of test trials made by each chick, the

TABLE V

Summary of data for group III, number of test trials, per cent of brightness choices and of choices of positions

Chick No.	Number of test trials	Brightness choices			Position choices		
		D	M	B	L	M	R
14	89	34.8	30.4	34.8	20.2	71.9	7.9
10	65	43.0	40.0	17.0	3.1	29.2	67.7
13	65	31.0	40.0	29.0	27.7	64.6	7.7
8	62	54.9	17.7	27.4		66.1	33.9
9	36	36.1	36.1	26.8	38.9	58.3	2.8
12	27	18.5	59.3	22.2	59.2	40.8	

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per cent of choices each chick made of each brightness value, dim, medium and bright, and the per cent of choices of each position, left, middle and right.

So far as brightness is concerned, the table shows little tendency of any of the chicks to select any given light consistently. On the other hand, some particular position, the middle position in four cases, the left and the right position in each of two other cases, was selected in over half the trials of each bird. Table VI indicates the development of this tendency. Chicks 14, 13 and 8

TABLE VI

Number of choices of left, middle and right positions in each ten trials for each chick of group III

Groups of ten trials[1]	Chick 14			Chick 10			Chick 13			Chick 8			Chick 9			Chick 12		
	L	M	R	L	M	R	L	M	R	L	M	R	L	M	R	L	M	R
1	6	3	1	1	4	5	5	3	2	3	7		2	7	1	6	4	
2		8	2	1	3	6	4	5	1	6	4		7	3		6	4	
3	4	4	2		1	9	4	6		5	5		5	5		4	3	
4	2	7	1		6	4	1	9		7	3			6				
5	1	9			2	8	1	8	1	9	1							
6	1	8	1		2	8	3	6	1	9	1							
7	1	9			1	4		5		2								
8	2	8																
9	1	8																

[1] The last group of trials for each chick includes less than ten trials.

show a very definite tendency to increase their choices of the middle position, while number 10 shows just as marked a tendency to increase its choices of the right-hand path. Numbers 9 and 12 had too few trials to show a progression very clearly, although 9 shows a rough approximation to a middle tendency.

These results, while throwing no further light on the problem of brightness selection, are interesting in indicating the selection of a direct, consistent route.

V. Discussion of Qualitative Data

1. Selective methods of adjustment. In making a study of this sort, the experimenter almost unavoidably thinks in terms of the conditions of his experiment as he knows them. Thus, the responses of the animals that are most interesting and significant to him are those that are in the direction of success. The errors

that the animal makes are an unavoidable but tedious accompaniment of the process. Such is the attitude in the concept of 'trial and error' learning. The lack of organization, the indirection of effort, the 'randomness' of the animal's behavior in the initial stages of learning are not in terms of what the animal is doing, but in terms of what the experimenter expects him to do eventually.

Observation of the chicks, and their objective records as well, show that, from the first, their behavior was characterized in general by definite methods of response, organized with reference to some aspect of the total situation. In the very earliest trials, disorganized as they appear, there is still a rough continuity and order in terms of the direction of the food box or of a way of escape. Persistent efforts to force a way through on the left or the right side appeared early in the learning. Some chicks persistently struggled with the gates on a given side, often until they were exhausted, or until they had pushed themselves between the wires. Another type of behavior which developed in most of the chicks was that of trying the end positions to the exclusion of the middle position in any compartment. This method, far from being perverse and stupid, is an appropriate reaction to a situation in which the two end positions are perceived in a unitary relationship with the center position, so that the conditions of the situation favor the end relationship twice as strongly as the center relationship. The vigor and persistence with which the chicks perceived this particular relationship was indicated in the previous section by the increase of errors during the period when it was at its height. So persistent and vigorous was this response that some chicks would repeat it twenty-five times or more in succession.

Another method which was evidenced as soon as the brightness situation came to be differentiated as a significant part of the pattern, was a tendency to repeat, in a given compartment, the choice which was successful in the previous one. So strong was this tendency that it was shown in inhibited form even in the later trials where perfect responses were made in the correct succession. This inhibited tendency was shown by gestures

toward the gates that were lighted in correspondence with the preceding free gate.

The correct response to the brightly lighted gate, the third of the series, was learned on the whole more quickly than any other part of the problem. In the earlier stages of the learning, before completely correct responses were made, this sort of response still indicated the beginning of an organized, differential behavior in terms of the successive pattern. Responses to the brightly lighted gate had to be made in terms of the relation of this gate as the last of the three, for, in any other place in the succession, it would have been an error. Furthermore, the typical sorts of errors described above constitute in themselves organized, selective adjustments with which the chick meets the problems created by more or less constant factors in the repeated situations.

It is inconsistent with conventional theories of learning that a chick, having adopted some more or less definite mode of adjustive response and having used it consistently over a considerable period of time, should abandon it for some new organization of behavior, often more adequate to the total situation. If the progress of learning depended upon the repetition of response, the practice effects from the persistent employment of some one particular mode of response would so establish that response that its abandonment in favor of some new organization would be impossible.

2. Cautious exploration. In the very early stages of the learning, the chicks in most cases attacked the gates with about all the force they were able to use. They often ran at the gates, throwing themselves against them, or sometimes they would go at the gates without the running start, forcing themselves as far as possible between the fastened wires, sometimes so far that their bodies would be wedged between the wires, and they would have to be extricated and started over again. A differential perception of the gates as gates to go through and gates not to go through seemed in many of the chicks to develop rather early. As early as number 5's twelfth trial, it approached the gates cautiously, looking and traveling about the compartment in an

exploratory way before making attempts. This sort of behavior persisted throughout the learning.

Individual differences are shown in the methods taken in this exploratory behavior. One chick might simply walk up and down the length of the partition, another might approach a gate, touching or picking lightly with his bill against the wires. Two chicks, one of which was number 5, frequently went from light area to light area, wiping its bill upon the glass. Several of the chicks, one in particular, developed the habit of knocking with the bill on the sheet-iron sill of the doors. Such tendencies pass over by gradual stages into the sort of behavior which might be called *mannerisms,* individual peculiarities, which, from the point of view of the observer, have little to do with the situation. An interesting mannerism of this sort was shown by one of the fastest birds, which began making the food call the moment it entered the first compartment, and continued it, at the same time increasing its speed, until it reached the food box.

The chicks were frequently observed to hesitate at the entrance, and then make directly for the correct brightness. Number 19 would frequently begin to make running movements even before being placed on the entrance-way to the first compartment, and very frequently made absolutely direct runs from the entrance to the gate of correct brightness.

VI. Summary

It was shown that the learning of a successive pattern of differential brightnesses, which, under the conditions of the present experiment, amounted to the perception of a temporal pattern, was possible for the chicks. Of the fourteen chicks of the first two groups, eleven had learned the problem by the end of the experimental period. Of the eight chicks of Group III, all of the six whose training was continued to the end of the experimental period had learned the problem involving two successive choices.

The performances of group I and group II on the whole and serial methods, respectively, were practically the same. In two of the measures used, average errors per choice, and average

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number of trials for learning, group II had a slight advantage over group I. In the third measure, average time per choice, group I had a very slight advantage. The smallness of the differences found, together with the range of individual differences observed to occur within each unselected group of seven chicks, points to the conclusion that the difficulty of the two methods was practically the same.

Further, the qualitative analysis of the behavior of the chicks in the two groups indicates that there is no essential difference in the character of the learning under the two methods. The introduction of the first new complication for group II constituted practically the presentation of a new problem in which an entirely new organization had to take place after the order of that necessary at the beginning with group I. With the introduction of the second complication, there is evidence that the 'principle', the general mode of adaptive response which the chicks had adopted with regard to the *M-B* situation, was applied in the new *D-M-B* situation. Thus, the loss in efficiency with the introduction of the second complication was less than with the introduction of the first, again showing a similarity with group I in the matter of increased efficiency as the course of the learning proceeded.

When the conditions were so arranged for group III that the chicks could make free choice of a path through the final compartment, it was found that, in general, they disregarded the brightness situation, and responded in terms of relative position. Each chick tended to develop a constant path, three taking the middle gate, one the right hand gate, and the two others tending toward the middle gate, although their number of trials was not great enough to show conclusively the final direction of the development.

Qualitative analysis of the performances of individual chicks showed that their learning could not be explained in terms of mechanical principles, but that it constituted a series of adaptive adjustments which the chick itself made in terms of the repeated stimulus-situation. Evidence was found for this view not only in the sharp and consistent drops in the learning curves of the chicks,

but also in the sharp and transient rises of the error curves which were shown from the qualitative data to represent in general the adoption by the chicks of definite and persistent modes of adjustive response, to be superseded, except in the case of those chicks which failed to learn the problem, by more adequate adjustments, until finally a completely adaptive mode of response was reached. The argument is advanced that, as evidence of organized, insightful behavior, the consistent modes of adaptive response on lower levels of organization, that is, those that are appropriate to a situation only partially grasped, are as significant in their sudden development and sudden abandonment, and are of exactly the same order of behavior, as the sudden appearance and consistent maintaining of the finally adequate response so much emphasized in most studies of insightful behavior in animals. Much individual difference was shown in the degree and efficiency of such organization of adaptive response, as well as in the quantitative measures of learning. In fact, the amount and nature of the quantitative differences between chicks depends just upon such qualitative differences.

Trials made under reduced illumination, while not perfect transposition experiments, were yet sufficient to indicate that the choices made by the chicks at each partition were based upon relative rather than absolute brightnesses.

VII. Historical Orientation and Conclusions

A study of the sort reported in this paper would not have suggested itself during the earlier period of animal psychology. Although its procedure involves a modified maze technique, and makes use of the well demonstrated capacity of chicks to discriminate brightness differences, the more fundamental aspects of the problem would not have presented themselves in a psychological atmosphere where the behavior of chicks in fairly complicated maze situations could seriously have been interpreted as Thorndike describes the performance of his chicks (1): "In such a series of associations, the response of one brings the animal into the situation of the next, thus arousing its response, and so on to the end. Three chicks thus learned to go through a

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sort of long labyrinth without mistakes, the 'learning' representing twenty-three associations." It would have been preposterous even to suggest that chicks might learn to adjust themselves to a situation which involves the nature of the completed response in the very first reaction. Or, in the period when the interest in the chick's psychology was confined largely to its visual discriminating ability, as such, in one of the most careful pieces of work done, Bingham (2, 3) reported as an interesting bit of observation, with no especial note of its systematic importance, the fact that chicks could respond to situations which varied as to the actual stimuli presented when the relations between them were kept constant.

Behaviorism, with its mechanical stimulus-response concept, while it advocated, even in the study of human psychology, the importance of careful observation and report of behavior, was precluded, by the limited character of the problems it set and by its preconceptions of the kind of responses these situations would invariably call out, from observing the significance of what the animal did in a given situation.

It remained for the more recent development of the study of animal psychology, instigated by the *Gestalt* movement in Germany and especially by Köhler's studies of apes and chickens (4, 5, 6), to apply the concept of insight to animal behavior. By demonstrating that animals perceive relations characterizing a total situation rather than discrete elements of those situations, that they may be observed to make appropriate, adaptive adjustments to situations of not too great complexity without having learned them previously, and thus that mechanical determination does not give a picture of animal behavior, a new field of animal research has been opened up.

Starting from the point of view and background briefly outlined above, this study has proceeded along the following lines:

1. The method of relative choice, found so fruitful in the study of insightful behavior in animals, has in these investigations been pursued and extended in its scope. In the pioneer investigations of this type of reaction, it has been methodologically valuable to maintain as simple situations as possible in order that the issue

might remain clear-cut. To this end, simple spatial situations have been employed using obstruction or transposition techniques, or more or less simple cases requiring the use of tools in situations, all phases of which were at once apparent to the animal in a unitary perceptual field. Although the validity of this sort of reaction has been demonstrated beyond doubt in such situations, the question remains as to whether some other sort of behavior is characteristic of the performance of animals under more complicated conditions. This investigation, by making use of a problem the very nature of whose solution involves rather complicated spatial and temporal relationships, and which, by the use of the transposition method was demonstrated to involve the relational judgment throughout, demonstrates that under the conditions which it set up, not only is the perception of temporal relations possible, but, further, the insightful behavior demonstrable in simple situations is equally demonstrable in situations of greater complexity.

2. A further aspect of the problem was a study of the performance of groups of chicks trained under the 'part' method and the whole method, respectively. Studies of the 'part' and whole methods have been concerned primarily with the practical problem of their relative efficiency. Although one of the interesting results of this phase of our study was the fact that no very significant differences in efficiency were apparent between the groups trained by the whole and by the serial method, the more significant aspect of the results has to do with the nature of the learning rather than with its efficiency or rapidity. Both the quantitative data and the qualitative observations of the performance of the chicks indicate that, under the conditions of this experiment, the 'part' method consists not of the addition of part to unrelated part, but of the nature of an expanding, related whole, essentially the same in its nature as the related whole developed under the other method.

3. The problem of chance reactions in animal learning has come in for much discussion, for example, in the theoretical discussions of Koffka (7), and Köhler's (4) discussion of the behavior of the animals in his experiments. In this connection, there are

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strong indications from our data that, when the chicks were placed in situations which, on the basis of a chance theory, should have brought out the chance reactions, they actually responded in a manner far more complex and adaptive than any determinations of chance could have accounted for.

4. Katz and Toll (8) and Köhler (4) have made observations on the characteristic modes of behavior of the individuals in their experimental groups of animals. An attempt was made in this study to keep as accurate record as possible of such differences both in speed and efficiency of learning and in the matter of characteristic types of procedure. The individuals differed widely in the speed of learning and in the consistency of performance after the learning had been completed. Further, they differed in their modes of adjustive response to the partially grasped situation, and in the readiness with which they adapted themselves to newly added complications of the problem. These individual peculiarities (personality trends, to use the terms of human psychology) were found valuable in interpreting the quantitative data of the learning curves. In fact, it is felt that the learning curves themselves mean very little unless their significance is seen in terms of the whole situation of the animal actively adjusting itself, in its characteristic way, to the conditions under which it is placed.

5. This investigation indicates that the errors the chicks made were often as good evidence of insightful, adaptive modes of response as were those more obvious evidences such as initial delay, and sudden rises in the curves of success. There is a tendency which has grown out of the need to demonstrate clear and unequivocal cases of insight, to confine the term to cases of adaptive response that are definite adjustments to the completely perceived relations of a situation. The results of this investigation indicate that to confine the term to so narrow a field is to leave unexplained a type of errorful behavior which is still not a product of chance or mechanical determination, and which shows itself upon analysis to be evidence of as complex adjustment as is possible in terms of the situation as the animal perceives it. To class it as behavior without organization or insight because it does not indicate organization of a type as complex as that which

would be the efficient response from the point of view of the observer, is a very anthropomorphic procedure. A further evidence that such behavior is truly adaptive lies in the observed fact that such partially successful modes of response, although practiced repeatedly, were quickly dropped and superseded by more complex and better organized adjustments as the problem became better defined.

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GOAL ACTIVITY IN THE WHITE RAT

by

ROBERT L. BRIGDEN

I. INTRODUCTION

The original purpose of this experiment was to make a qualitative study of the behavior of white rats as they learn to make complex choices. Although it became obvious within 200 trials that the problem was too difficult for the rats, the experiment was continued in order to see what sort of a solution the rats would make. Several facts were discovered which show the inadequacy of some older concepts and suggest alternative explanations.

For this study a maze was used having three identical subways leading from a platform at the starting place to a similar platform at the opposite end, on which the food goal was placed. The value of such a maze or choice box employing subways lies in the fact that the stimulus-lights may be at the level of the rat's eyes as he approaches the pathways.

II. METHOD

The original purpose of this experiment was to determine whether the rats could learn to choose the proper path to the goal, from combinations of three vertical lights, located over the center subway. Filters were used to regulate the intensity of the lights whose relative brightness was always the same for a given pathway. The paths were named *A, B, C,* and an arrangement of lights was assigned to each. For path *A* the brightest light was at the top, a medium light in the middle, and a dim light at the bottom. For path *B,* a dim light was uppermost, a bright light was in the center, and the lowest was of medium brightness. Path *C* had medium uppermost, dim in the center and bright at the bottom. (See Fig. 1.)

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If the correct path were *A*, paths *B* and *C* would be closed at the goal-end *(G)* with wooden blocks. The rats were placed at the starting place *(St)* by the experimenter and allowed to find their way to *(G)*, regardless of how many 'wrong' alleys they entered. The path from *St* to *G* constituted a 'run'. The rats were given six consecutive runs both morning and evening.

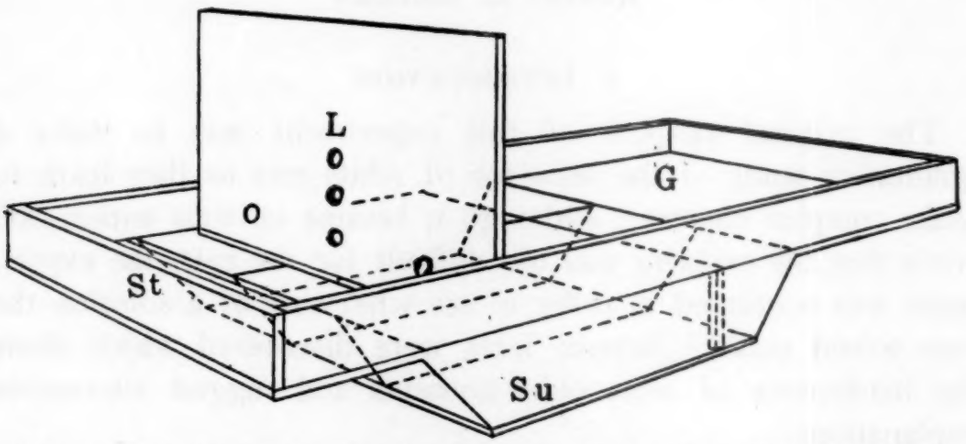

FIG. 1. Rat Apparatus Showing Subways (Su), Start (St), Goal (G), and Light Patterns (L).

Records were kept of the stimulus-patterns, the paths entered, and of the rat's behavior during each run. The first few runs were timed.

To prevent the formation of place habits, the stimulus-pattern was changed after each run.

On the 'follow-up' experiments the same technique and apparatus were used except that the position of the stimulus was altered in a way that will be explained under the heading "Additional Experiments."

Seven rats, of two litters, three months old at the beginning of the experiment, were used. Five of these, three males and two females, were used during the entire experiment.

III. RESULTS

The behavior of the rats, the first time they were in the apparatus, was characteristic of rats in a new situation. They investigated all the pathways and platforms and seemed to be particularly partial to the dark alleys which led from the starting

platform to the goal platform. The time required to find the food varied from 20 seconds to 6 minutes and 40 seconds, depending on how active they were and the path they followed. They were not accustomed to being handled and usually carried the food down into the dark alleys to eat it.

On the second trial, two types of behavior appeared. Four of the rats, having found food once, set out to find it again by following the path of their first run. They cut corners more closely, ran faster and seemed to have a definite, motivating goal. The other rats went into the dark paths and remained there for varying lengths of time. Their goal, apparently, was to hide.

On the third trial one of the rats, after trying both of the closed paths, gave up that method of reaching the food, climbed over the stimulus panel, and reached the goal by the overhead route. This was similar to the behavior which Helson[1] observed in some of his rats. Another rat, when it had eaten its food at *G*, climbed back over the stimulus-panel and returned through the path it had just followed.

The tendency of the rats at first, when they had chosen an incorrect path, was not to return and try another, but to 'nose-up' the block which covered the exit from the wrong path into which they had run. They would keep at this for some time, and more than once a rat was able to push up the block and wriggle through even when the experimenter held it down. On the first day none of the rats looked at the lights, as far as could be observed. On the second day, one of the rats, on its fifth trial, placed its paws and nose close to the lights and happened to make a correct response. The next day two of the rats acted in a similar way. No correct use of the lights, in relation to the paths they represented, took place, however.

During these first days, the most apparent fact was the obvious presence of a goal in all of the rats' activity. The experimenter's goal was for them to respond to the lights, and although none of them did, the behavior of each rat indicated motivation by a more or less clearly differentiated end, which changed from time to time. The outstanding goal seemed always to secure the food

[1] Helson, Harry. Insight in the white rat. *Jour. Exp. Psychol.*, 1927, 10, 378.

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as quickly and directly as possible. In the following paragraphs will be traced the manner in which, during the three months of experimenting, they continually reduced their errors and the length of the path, without perceiving the problem intended by the experimenter.

During the first ten days, when the rats made a wrong response at first, particularly when the stimulus was *B,* they would run wildly into the two wrong paths again and again, seem completely confused, and then often return to the starting place *(St)* and begin again. Sometimes, after a number of these incorrect attempts, they would enter their favorite alley (at first they showed preferences for particular alleys) and remain there, in the dark, indefinitely. At other times a rat would make almost a correct set of responses, showing evident insight with respect to the problem. The next day, however, it might make 8 or 10 errors.

By the tenth day, after 60 correct responses for each rat, all of the animals, judging from their behavior, perceived the total situation in the light of a release from hunger tensions. From this stage on it became a problem of systematically hunting for the correct path. At no stage of the experiment was ' trial and error ' apparent. There was always a goal with respect to which the animal's behavior was organized. This is substantiated by the following examples.

One of the first general methods which they pursued was to try the path which last time had led to the goal, the path which, according to their most recent experience, was the shortest route. If *A* were the correct path for the first run, they would try *A* first on the next run. Since the same stimulus was never used twice in succession this behavior pattern was unsuccessful and was soon abandoned. Obviously this performance was the direct antithesis of ' trial and error ' behavior because in terms of the situation which confronted the rat, an organized response was made to the conditions which had been discovered.

By the second week none of the rats tried to push up the covers of the wrong paths. *Instead, they would go a shorter and shorter distance into the tunnels.* This process continued through-

out the course of all the experiments. At the end they traversed less than half the length of the tunnel, and in some cases, failed to enter far enough to see the other end. Hence they sometimes returned although they might have chosen the correct path.

By the end of the second week, four of the six rats (one had died) were using definite sequences. One went *A, B, C,* 83 per cent of its runs during two weeks until it found the correct alley; another went *C, A, B,* 88 per cent of its runs during two weeks. These sequences changed from time to time. Another, that held to the sequence *A, B, C,* came running out of *A* one day so fast that it could not make the turn into *B* and entered *C,* which happened to be correct. This was enough to change its sequence. During the next 8 days, it was *A, C, B* in 91 per cent of the runs.

At the end of about three weeks, another event was noticed, which recurred several times. The correct stimulus was *B.* The rat ran into *C,* came out, returned, and came out, five times. It ran in and out as fast as it could, finally came out and went into another path. The same day still another rat did the same thing. The stimulus was *A,* and as the previous rat had done, it ran in and out of *C* five or six times. Other rats behaved similarly at various times. The fact that this behavior was repeated by the same rat and by other rats indicated that it was not just random movement or a chance performance, but rather that it was a necessary and orderly relieving of some tension, although the performance was ' unintelligible ' to the experimenter.

During the second month it occurred to the experimenter that the rats were avoiding the tunnel which had been correct on the preceding run. Since the same path was never used twice in succession this meant that the rats were not only reducing their number of errors, but also that they were eliminating a changing position! If *A* were the correct path the first run, they would not go into *A* on the second. To overcome this the same path was sometimes repeated on two consecutive runs. This bothered the rats, and when after running *A* the first time, they went *B* and *C* and both were closed, they were as confused as they had been in the first days of the experiment, when, instead of going to *B* correctly, they would shun it and go to *A* and *C* alternately.

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This did not continue over twelve runs, however. Their errors increased and they reverted to their series runs: *the surest way to get to the food with not more than 2 errors.*

Since no new behavior patterns appeared in the following three weeks, it appeared that the rats had achieved the greatest degree of insight that was possible in the experimental situation. As a simple test to find out what effect, if any, the lights had on the rats' behavior, a schedule of correct paths was prearranged, and the rats run with the stimulus-lights off. They ran just as they had when the lights were on. Then this part of the experiment was terminated.

IV. Additional Experiments

In order to learn whether the inability of the rats to choose the correct paths by means of the lights was dependent on the apparatus or the rats, two additional experiments were performed. In both of them the same apparatus, technique and rats were used as before, except that the location of the lights was changed.

In the first test-experiment, three horizontal lights were employed, one over each subway entrance at the same height as the middle light of the vertical series previously used. A bright, a medium and a dim light were used, and all the rats were to respond to the brightest light. The intensities of these lights were the same as in the main experiment.

The rats were familiar with the apparatus and rapidly solved the problem. It required from 50 to 80 runs for the rats to choose the correct path consistently. There were no striking attempts at solution apparent as in the preceding experiment. It was a case of gradually reducing mistakes, requiring about 20 to 30 runs, and then, suddenly, a 'burst of insight' after which they would run almost perfectly. When they were able to choose the correct path first in a majority of the runs in any series, they would walk slowly and tensely toward the passages, selecting their path more by the light in the pathway itself than by the overhead stimulus-light. The only effect of 'practice' was to make their reaction faster. They were finally able to run at top speed from *St* to *G* without a sign of hesitation.

In the second experiment all three stimulus-lights were placed horizontally over the entrance to *B*. At first they went to *B* all the time, a carry-over from the last experiment where they had been responding to the brightest lighted pathway rather than to the light overhead. It required from 30 to 50 trials for all the rats to run correctly. This, too, was so easily solved that no new striking methods developed by which the rats reduced the length of the path.

V. Theoretical and Conclusions

One of the most outstanding facts observed during this experiment is the *unity of each response*. All movement is composed of a start, the movement proper, and the end. The 'movement proper' is obvious; also it is necessary for the movement to begin and eventually to terminate. The unity of these three is not, however, as readily accepted as the necessity of their existence. Unless the start, the direction and the goal were parts of a single configuration *there could be no orderly behavior*. Without a goal there would be no need for a start and unless the movement relieved tension by leading to a goal there would be no reason for the movement. The three are interdependent parts of an orderly unit of behavior.

A good example of the necessity and importance of the start not only as a beginning place, but also *as a factor in orientation* is furnished by the behavior of the rats. As has been mentioned, when they were unable to find the correct alley after a number of trials, they would return to the starting place, reorient themselves and proceed to run again. Although the start is important, it only acquires this importance because of its one-ness with the response as a whole. *The start is meaningless unless there is an end set up.*

Evidence that tension makes intelligible the 'movement proper' is particularly striking in the early trials, when the rats, after running into a closed alley, would try to open it and get directly to the food rather than to return to the starting platform and begin again. This behavior was also evidence of least action. The rat was attempting to reach the food over the most direct

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route. The demand for release from tension was again very obvious in the last weeks of the first experiment when various delays were introduced as punishment for entering incorrect alleys. The rats would struggle to get through; they would fight and tear at any obstruction placed in the path to the goal. The rats were expending energy in preventing the obstruction from destroying the unity of the food-getting behavior. In this connection some of the rats became reticent about entering alleys at all, evidently anticipating lack of success. Instead, they attempted to climb over the top, or scale the side wall of the apparatus. There was no break in these responses; no evident adding together of elements. The response was one continuous reaction each aspect of which was obviously directed toward the goal.

A second conclusion from this experiment pertains to the fallacy of the double standard in explaining behavior. When the experimenter watches a rat run back and forth between two incorrect passages and describes a rat's behavior as trial and error, he is seemingly as incorrect as a man who explains the lost steam and the friction of a steam engine by means of 'random movement'. The rat is following a set of laws as real, as definite and correct as those obeyed by the 'steam engine'.

In terms of the experimenter's problem, errors were involved in the rats' behavior, but to explain the rats' behavior in terms of the experimenter's desire is obviously as incorrect as to explain the friction of the steam engine in terms of emotion. Events must be explained in the light of the conditions which surround them at the time and according to the way in which each condition is related to the whole of which it is a part. The practical expedient of measuring the learning process in terms of errors has been allowed to dictate a theory of learning, and has led to a false standard of comparison, irrelevant to what the rat is actually doing.

The way in which several of the rats ran in and out of a path a number of times, before trying another, has already been mentioned. No obvious explanation is apparent. 'Trial and error' would be an easy way of admitting ignorance, but would neither

explain nor describe the behavior in terms of its own surrounding conditions. To hazard an explanation in terms of dynamics: when the rat entered the subway, which might have been open and the means to the goal, a tension was relieved. When he started down the incline, darkness at the other end, or even at the middle of the alley might have been perceived, rat fashion, as indicative of failure. This behavior was subordinate, however, to that of reaching the food, whose position was known, hence did not suffice to overcome the tension in the direction of the main goal. The rat, therefore, returned into the alley.

A third suggestion, arising out of this experiment, is concerned with the *relativity of insight*—the ability to see the complete relation between a part and the whole from which it is differentiated. Insight is not static and limited. It expands and differentiates in an increasing awareness of the relations of the parts to the total situation.

The first time the rats were placed in the apparatus, their reactions were quite different from the last times. At first they were frightened, ignorant of the food as the goal, and unaware of the existence of three paths of which two were closed. It was only as they learned of these parts and something of their relations that their "errors" could be cut down, and they could secure the food more quickly. The choosing of sequences of alleys and the reduction of errors by eliminating entrances into alleys on one trial which had been correct on the previous run, are examples of the way in which insight differentiates and expands. The apparatus was no longer a maze, but an ordered problem in which one of three entrances would lead to the food.

VI. Summary

1. White rats, in this experiment, were unable to choose the correct of three paths to a food-goal when the stimulus-pattern was a combination of three vertical lights.

2. The same rats could choose the correct path if the same combinations of brightnesses were placed horizontally, either one over each path or all over the middle path. This shows that they

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could discriminate the lights and that the original behavior was not due to a defect in the lights.

3. A response may be divided into three aspects, the start, the movement proper, and the end or goal. No movement exists without all three. The goal must be set up before the act takes place since, without it, the act never starts.

4. 'Trial and error', either as an explanatory or descriptive concept, is anthropomorphic, committing the fallacy of the double standard, and is dynamically unintelligible.

5. Insight in rats is not static and fixed. It expands and differentiates in an increasing awareness of the relations of the parts to the total situation.

THE PROBLEM OF INSIGHTFUL BEHAVIOR

by

ERNEST K. PATTON

CONTENTS

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I. STATEMENT OF THE PROBLEM

The problem investigated in this experiment deals specifically with the emergence of insightful behavior.[1] Light stimuli were arranged in two pairs (Fig. 1) which could be varied in intensity so that each member of a pair presented, with its neighbor, a relation of greater difference or lesser difference or greater summation or lesser summation when compared with the other pair. This method carries the conventional apparatus employed in experiments on relational judgment and transposition a step farther and requires the subject to compare the relationship between the lights of one pair with the relationship between another pair rather than to compare directly the intensity of one light with that of another. In order to bring out the insightful mode of response from its very beginning in the problem situation, no verbal instructions were given the subjects who were left to their own ingenuity both in discovering the problem character of the experiment and in ascertaining the principle of the correct choice.

[1] The problem was originally suggested by Dr. P. C. Squires.

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II. Historical Background

The present study made use of human subjects, but the problem involved finds its sources in both the human and animal experimentation of the past forty years.

In 1911, Hamilton (6) devised a choice apparatus for studying ideational behavior. He found striking differences in the modes of activity of various mammals. His method of experimentation was ingenious and Yerkes (23) took it as the basis of his multiple choice apparatus for testing the mentally defective. We quote from Yerkes' article, " Now it happens this relational method of studying ideational behavior has several points of merit for those comparative psychologists who seek to apply precise methods of studying behavior to the materials of the psychiatrist. These merits, it must be admitted, are not accidental, but instead result from the requirements which I had in mind in devising problems, apparatus and procedure. The most important of them may be described thus: (1) A series of problems ranging in difficulty from the very simple and easy to the extremely difficult may be selected, standardized and presented, either in part or in entirety, to any given subject. (2) Each of these problems is completely soluble by a subject with excellent ideational capacity, although not necessarily by a given subject. (3) The attempts of the subject to solve a problem are readily recordable as forms of reaction for the most part as definite choices of objects in a group. The experimenter may, however, make time measurements and keep, if he so desires, detailed records of behavior between choices. (4) Introspective data supplementary to those recorded obtained, it is important to request of the subject, if linguistic reaction is possible, a definition of the right object or a description of the method of selecting it. (5) Graphic representations of the process of solution, ideational or otherwise, are possible. Such, for example, are curves of learning constructed on the basis of right and wrong choices; coefficients or indices of ideational capacity may also be used. Likewise formulae descriptive of the mode or modes of reaction, reactive tendencies or methods of choice become available."

Yerkes (23) took Hamilton's suggestion as the basis of his multiple choice apparatus for testing the mentally defective. He says, again, "Experience indicates that the relational test has considerable value in mental examining as well as varied value as a method of research" (p. 379). His multiple choice method was used by Coburn and Yerkes (4, 5) in the study of the crow and pig, and by Burtt (3) in the study of the white rat. Brown and Whittell (2) used it in the study of human adults, and Yerkes (23) perfected his method in his study of the mentally defective and deranged as compared with normal individuals. As early as 1902 Kinnaman (10) had discovered the ability of monkeys to perceive relative brightness and Yerkes found that they possessed a type of ideational behavior. More recent developments have disclosed certain 'abstractive ability' in apes, as Révész (16) discovered, but it remained for Köhler (12) to do his monumental work with apes in which he found insightful activity in the perception of relationships and objects in relation to goal activity.

More recently Helson (8) describes the presence of insight in the white rat, and, passing down the animal scale, the 1930 study of Wheeler and Perkins (21) shows definite insightful activity in the learning of the goldfish.

Turning to human subjects in the matter of puzzle solving we go back to the investigation of Lindley (14) and Book (1), and come to the crucial examination in the work of Ruger (17) who studied twenty-five subjects in the process of solving mechanical puzzles. He found much 'random' exploratory behavior, with a large proportion of first solutions seemingly accidental. But, he also found, frequently, a sudden and permanent drop in the learning curve. Attitude played a large part in the effectiveness of the analysis. The reports of his subjects seemed to reveal, so he thought, many processes which might be classified either as perception or reasoning. He made out the case for transfer which he attributed to similarities between situations. Wyatt (22), in his analysis of Ruger's experiment, says, "The moment or act of insight can only sometimes be described as a sudden flash; it is often a succession of glimmering apprehensions and is found

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in all degrees, from elusive and indefinite dimness to a clear and convincing definiteness."

In this experiment we are concerned with the views of insight taken by Köhler (12) and defined by Helson (8). "Insight," says Helson, "may be defined in a number of ways and may be tested through a number of criteria, such as ability to respond to a part in the light of a whole, modification of activities to meet the exigencies of a situation in a manner we may call sensible, or the transposition of the general properties from one situation to another; but in no case do we mean by insight any mental process, a peculiar vitalistic entelechy or anything not objectively observable."

An excellent review of Ruger's work is found in Murphy (15) which is general and historical. The *Gestalt* conception and interpretation of Ruger's work may be found in Koffka (11) and the recent organismic view in Wheeler (20) while arguments opposed to this conception are given by Hunter (9) in his article on "Experimental Studies of Learning."

III. Description of Apparatus

A visual pattern was prepared consisting of two pairs of apertures in a black cardboard screen. The apertures were circular, 2½ inches in diameter; the members of the pairs were 1⅞ inches apart and the pairs 8 inches apart. Behind each aperture was mounted a milk-glass plate. Just above and between the members of each pair was mounted a miniature light bulb for a signal light. The rest of the visual field was black. The lights were placed on a level with the eyes of an average person seated, or 17¾ inches above table level. The position of the subject (Fig. 1) was arranged at a table, with a distance of 54 inches from the presentation screen to the subject's eyes. A head-rest was used. Two keys similar to telegraph keys were mounted upon the table in a position convenient to the subject's hands and were connected with the appropriate signal lights. Behind the milk-glass plates were tubes, 3 inches in diameter and 9 inches long, of white asbestos material to provide diffusion. To remove shadow from the milk-glass cast by the Aubert diaphragms when

nearly closed, thin frosted glass plates were used in front of the Auberts. This made a double filter and gave even illumination of the milk-glass at all intensities. Aubert diaphragms of special construction were used to vary the light intensities. These were constructed in such a way that sliding controls with scaled metric readings made accurate settings possible and provided a gradation of intensity from no light to very bright. Behind the Aubert diaphragms four asbestos lined compartments contained the 150-watt daylight bulbs mounted and carefully centered. A variation in the quality of light of the first Mazdas tried made it necessary carefully to match four of the same quality so that the subjects

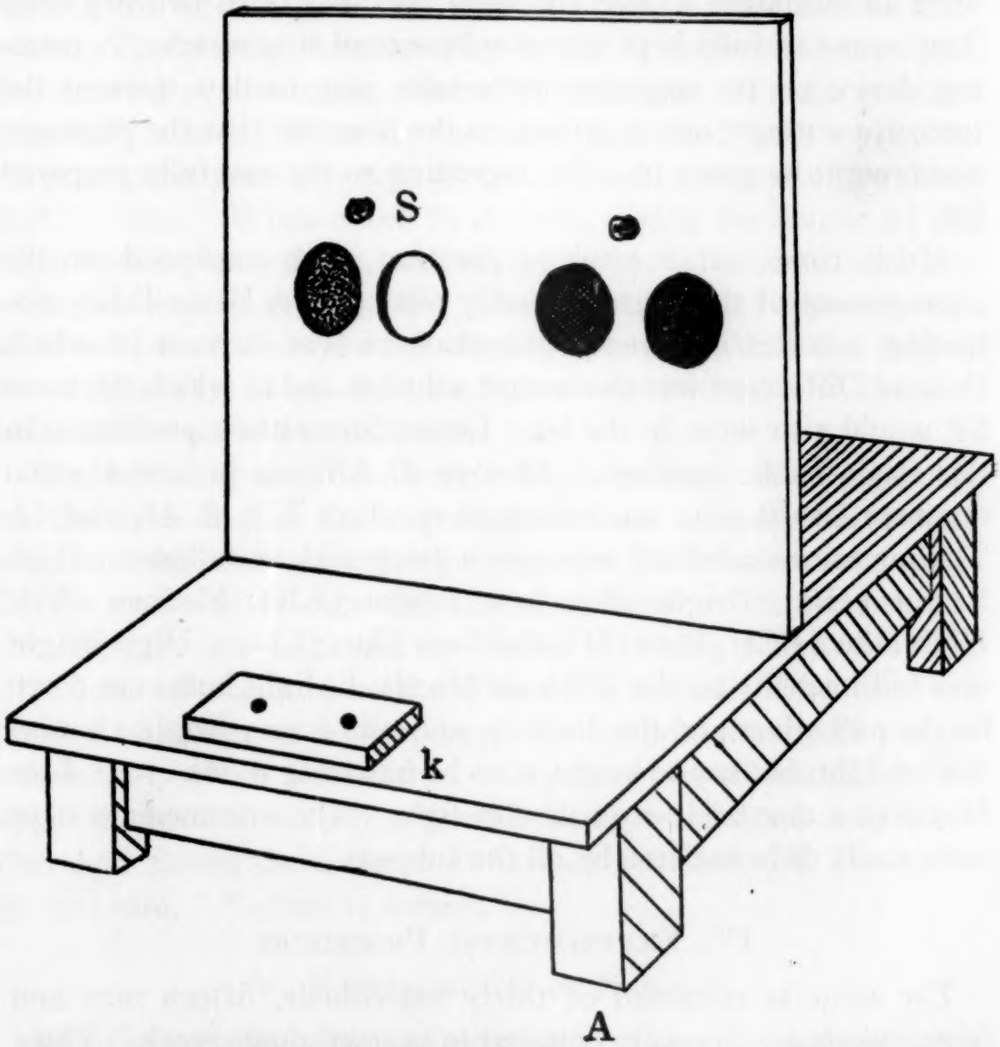

FIG. 1. A. View of Apparatus Showing Paired Lights. S, Signal Lights; K, Response Keys.

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might detect no difference. Ventilators were placed over each light.

The wiring of the apparatus was so constructed that a main switch, three-pole, double-throw, would cause the right or the left side to be correct and would permit the subject, by pressing the key on the correct side, to light a signal light above the correct pair. Also little signal lights before the experimenter on his table informed him as to the correctness or incorrectness of the response made, and the time of response. A correct response caused two little lights to glow on the appropriate side, while an incorrect response caused only one of the little lights to glow. These lights were all miniature in size and were operated from two dry cells. Time was carefully kept with a split-second stop watch. A rotating device on the experimenter's table was used to present the intensity settings, one at a time, to the observer that the presentations might be given in order according to the carefully prepared list.

Much time and careful preparation were expended in the arrangement of the list of intensity settings. A Basic Table containing a series of twenty presentations was devised in which Greater Difference was the correct solution and in which the same list would also serve in the later Lesser Summation problem. In this Basic Table, numbers 1–15 were all different in intensity and numbers 16–20 were repetitions of numbers 3, 6, 8, 11, and 12. The intensities used fall into seven categories as follows: High Bright (HB), Bright (B), Low Bright (LB), Medium (M), High Dim (HD), Dim (D), and Low Dim (LD). High Bright was full intensity of the 150-watt Mazda daylight bulbs cut down by the milk-glass and the distance, and was a very bright circular disc of light, but not so bright as to be irritating to the eyes. Low Dim was a disc of just discernible light. The intermediate steps were easily differentiated by all the subjects.

IV. Experimental Procedure

The subjects consisted of thirty individuals, fifteen men and fifteen women. Six were engaged in post-graduate work. Three were college graduates. Twelve were undergraduates from the

psychology classes in the University. Seven were students from the High School. One was from the eighth grade and one from the first, and for a special test, one four-year-old pre-school child was used. The subjects were chosen because of availability.

In our method of procedure, a dark room was used. The subject was seated comfortably before the observation table, and the head-rest adjusted. The hands were placed upon the table and the fingers upon the keys. *The subject was purposely given no verbal instructions.* The four lights were already turned on equally when the subject came into the room. The subject was shown (by non-verbal demonstration) the use of the keys in lighting the signal lights. He was then asked to describe the situation. The words, " please describe the situation in which you find yourself, and what do you see? " were used. To the question invariably asked, " What do you want me to do? " the reply was, "As the experiment proceeds please respond in any way you think best." Also, " When asked to describe during the course of the experiment, please do so, and tell just what is in your mind and why you respond as you do." The subjects very frequently volunteered information during the experiment. With the subject as nearly at ease as possible, the lights were switched off, the first presentation set and switched on.

The following method of recording was used: Two pages lay on the table before the experimenter, one a quantitative data sheet and the other sheet for introspective and observational data. On the quantitative data sheet the correctness or incorrectness of the response was indicated by a plus or minus followed by the time interval accurate to the fifth of a second. The first key pressed was taken as the response. On the presentation of pattern number 14, which consisted of two pairs of equal intensities, the subjects characteristically pressed both keys simultaneously when they had solved the Greater Difference problem. A few spoke up and said, " Neither is correct."

V. Presentation of Results

(1) Quantitative Data (Statistical). Careful tabulation was made of the number of the subject, the age, sex, school status,

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total Greater Difference presentations before solution or full insight, the number of correct and the number of incorrect choices, the total Lesser Summation presentations before solution or full insight and the number of correct and incorrect

TABLE I

Statistical data

No.	Age	Sex	School status	Total G.D. to insight	Plus	Minus	Total L.S. to insight	Plus	Minus
1	19	M	C	23	13	10	*75	50	25
2	20	M	C	66	54	12	15	12	3
3	20	M	C	42	21	21	7	4	3
4	14	M	H.S.	81	56	25	31	23	8
5	16	F	H.S.	80	53	27	52	39	13
6	16	F	H.S.	66	41	25	78	60	18
7	20	M	C.P.G.	6	3	3	46	29	17
8	20	M	C (Summer)	315†	149	156	82	52	30
9	21	M	C (Summer)	100	61	34	15	9	5
10	22	M	C (Summer)	89	43	26	49	43	6
11	26	M	P.G.	6	0	6	14	9	5
12	14	M	G.S.	94	38	56	22	13	9
13	28	M	P.G.	114	70	54	38	19	19
14	65	M	C (Summer)	74	50	24	35	20	15
15	35	F	C (Summer)	78	37	41	37	23	14
16	28	M	C (Summer)	110	82	28	‡No L.S. given		
17	20	F	C	57	34	23	27	20	7
18	20	F	C	40	25	15	35	24	11
19	37	F	P.G.	36	21	15	29	20	9
20	20	M	C	40	31	9	‡No L.S. given		
21	40	F	C.G.	33	22	11	30	21	9
22	16	F	H.S.	64	38	26	16	11	5
23	22	F	C.G.	40	26	14	22	13	9
24	7	F	G.S.	112	65	49	30	24	6
25	4	M	P.S.	§	48	32	§No L.S. given		
26	18	F	H.S.G.	60	36	24	20	11	9
27	16	F	H.S.	60	40	20	‡No L.S. given		
28	27	F	P.G.	40	28	12	20	14	6
29	25	F	P.G.	38	18	20	14	9	5
30	24	F	C	56	35	21	31	20	11
				2077	1237	840	869	592	277
			Approximate ratio		60	/ 40		68	/ 32

Legend: G.D., Greater Difference. L.S., Lesser Summation. M, Masculine F, Feminine. P.S., Pre-school. H.S., High School. C, College. C.G., College Graduate (not in school). P.G., Post-Graduate (enrolled).

* No. 1 made no complete solution of the L.S.

† No. 8 gave a series of short sittings which proved unsatisfactory and helped lengthen the time necessary for solution.

‡ Nos. 16, 20 and 27 had to leave before the L.S. could be completed.

§ No. 25, a four year old child, became restless and very tired in the dark room after 80 presentations and the attempt was abandoned. However, the performance curve was then at a point 22 steps above random, showing insight in the attempt at solution.

choices. The first subject did not fully solve the Lesser Summation problem so far as giving a clear verbal statement is concerned, but after 75 presentations, *while declaring that there was no solution,* nevertheless, gave a record of approximately correct choices. Number eight was the quickest of the thirty subjects in average reaction time. He was unable to complete the experiment on the first day, returned later for another sitting, and finished on the third day, which made his work long drawn out and unsatisfactory. His reactions were too quick to be accurate.

(2) Quantitative Data (Graphic). The experiment revealed the possibility of plotting three curves for each subject, the Basic Performance Curve based on correct and incorrect choices, the Learning Curve derived from it based upon the percentage of correct choices in groups of five, and the Time or 'skyline' curve of reaction-times in seconds. This 'triple curve' method reveals striking similarities in a few cases and in others wide differences. To illustrate similarity, the Greater Difference Performance Curves of Nos. 2 and 20, both University students of comparable standing were almost identical. In Fig. 2, we see

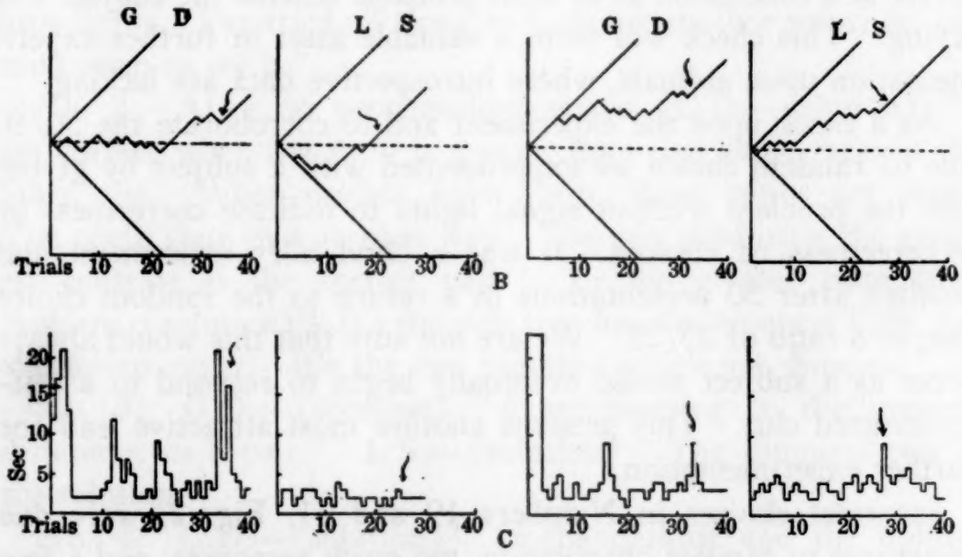

FIG. 2. B. Performance Curves of Subjects 19 and 21. G.D., Greater Difference; L.S., Lesser Summation.

C. Time Curve of Subjects 19 and 21, showing 'Sky Line'.

The point of full insight or solution is indicated by the arrow. Note the 'sky scraper' in the time curve denoting a period of deliberation just preceding solution.

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the Triple Learning: Performance, and Time Curves of subjects No. 19 and No. 21 showing variations and clearly indicating in the 'skyline' time curve the 'skyscraper' pause before solution. This pause, or 'initial delay' is similar to Snoddy's (18) initial delay in mirror-tracing. Our subjects *invariably* made this very noticeable pause. (The Learning Curve omitted from Fig. 2.)

As a check on introspective data we prepared a chart of performance curves for the first 20 basic table items showing the curve resulting from various plans or schemes which the subject might try before arriving at the correct solution. We found that choice of the brightest member would result in a falling performance curve ending 2 to 6 steps below the starting point. Choice of the dimmest member would end 8 to 14 steps above. Greatest Difference would of course be the solution and would be ended 20 steps above. Choice of Lesser Difference gave a drop of 20 steps. Choice of Lesser Summation (incorrect in first problem) would give a rise of 8 steps. Greater Summation would give a fall of 10 steps. Choice of intermediate intensities gave 2 to 10 steps below. By this means we could check introspective data and arrive at a conclusion as to what probable scheme the subject was trying. This check will form a valuable asset in further experimentation upon animals, where introspective data are lacking.

As a check upon the experiment and to corroborate the 50/50 line of random choice we experimented with a subject by giving him the problem without signal lights to indicate correctness or incorrectness of choices. It was a blind alley experiment and resulted after 50 presentations in a return to the random choice line, or a ratio of 25/25. We are not sure that this would always occur as a subject would eventually begin to respond to a self-constructed clue. This presents another most attractive lead for further experimentation.

Incorrect choices in Numbers 19 and 21, Fig. 2, were due sometimes to careless observation, too quick responses, and a few times in other subjects to defective eyesight. The subjects, following a mistake in the training series, invariably gave the reason for the mistake as the introspective data would show.

(3) Qualitative Data. We present typical introspections of

the subjects during and following the solution of the problem. At critical times during solution and as soon as possible after the behavior of the subject indicated that the problem had been solved, introspective data were called for and recorded by the experimenter.

No. 1. After 23rd presentation. G.D.[2]—(solution) "If the successful reaction brings the light, I think I have discovered the correct solution. It is a reaction to the pair which in each presentation seems to hold the same relative position or relationship. In the pair selected there is greater variance between the components of the correct pair than there is in the case of the other pair and the two components of the unselected pair are more similar in intensity or brightness."

In the second problem (L.S.) this subject did not discover the correct solution the first time it was presented. "I think something has gone wrong with your signal lights. I am disregarding them now and am still operating upon the same plan." Another sitting was arranged and the final result was that the subject's behavior came to a correct solution, but the statement was "that isn't according to my principle but is correct according to the little lights. I've tried all along to look for another principle, but can't seem to see it."

No. 2. After 66 presentations stated (G.D.—solution) "I am correct when the ratio is greater than that same ratio in the other one. When neither light lights, those ratios are equal. You could state that another way. The pair producing the greatest contrast is the correct pair." In the greater summation problem, (solution) "It's the side that has the dimmest light, but exceptions occur. It's the two together which are dimmest."

No. 3. G.D.—(solution) "I am reacting to the greatest difference in a pair." L.S.—(solution) "The dimmest pair is the solution."

No. 4. G.D.—(solution) "If the darkest and the lightest are both on one side, it is right. If both sides are equal, neither is correct." L.S.—(solution) "The side with the darkest one or ones is correct."

[2] Greater difference. L.S.: Lesser summation.

No. 5. G.D.—(solution) "The brightest and the dimmest eye go together. An equal pair are never correct." L.S.—(solution) "The pair that has the dimmest lights."

No. 6. G.D.—(solution) "When the brightest and the dimmest are on one side, that's the side." L.S.—(solution) "Its the dimmer pair. I mean the two together are dimmer."

No. 7. G.D.—(solution) "Its the dim member and the bright member, the largest difference. The side that has the greater difference or the largest phenomenal difference." L.S.—(solution) "Its the dimmest set of two lights taken as a whole. The configuration that has the least brightness."

No. 8. G.D.—(solution) "Well, its the pair with the most difference in intensities. That's the proper one. I didn't reason it out at first. Then I thought of the brightest light. Then I thought you were trying to form a habit and were changing them as you pleased. Then I tried memory, north side, south side, and how many times. Then it came to me all of a sudden. As soon as I described, I saw it." L.S.—(solution) "Its the single dim light, or something on that order. Its the two dim ones or the dim one."

No. 9. G.D.—(solution) "I've thought of a possibility. I have a hunch. The idea came and sort of cleared up. It is the side with the greatest difference." L.S.—(solution) "It's the pair that has the least light of all, as a whole. It's the side that doesn't seem to have a very bright light in either one. The correct pair doesn't have as much light as a pair."

No. 10. G.D.—(solution) "The two on the left are about equal. The two on the right have a wide difference. That is, I'm hitting the side that has the greater difference between the two lights." L.S.—(solution) "I pressed the side that had the single dimmest light and then the dimmest pair, which is correct, I'm sure."

No. 11. Trained observer. G.D.—(solution) "You react to the pair with the greater difference in intensities. A knowledge of psychology in general would help in this experiment. In looking between them (the pairs) its a total situation, a unity, the whole thing. L.S.—(After 7th presentation) "Oh,

oh, I see what you're doing. Wait a minute. You are adding another complication. Here's what you could be doing. Wait, I'll try the next one. I have a notion. I tried least difference. I guessed wrong. Its a process of elimination." (After 14th presentation—solution) "I chose the least total brightness." Final statement: "An interesting problem grows out of this. A curve of responses could be plotted. Another thing, the bright pair pulls, the eye turns to the bright light."

No. 12. A grade school boy. He tried various schemes. 14 A. "I'm not getting them right." 19 A. "I don't know. Is there a plan?" 5 B. "I used the bright light, then the opposite." 9 C. "I did the wrong one, but I've thought of a plan that worked once or twice. When a bright one and a dim one are together in a pair, it worked twice." (Didn't stick to this solution.) D. 20. "I haven't got the plan yet." E. 14 (solution). "I think I have it now. It's the one where there's the most difference between the shades of light." L.S.—"That's different. Have you changed it?" F. 5. "I pressed the one that had the most difference. You've changed it to the one with least difference haven't you?" F. 6. "Least difference didn't work that time." F. 7. "Is it the one with even lights?" F. 16. "Leave it on a little until I see if I can figure it out. All right, I think maybe I've got it." G. 2. "It's the two dimmest lights." (Final statement) "The first was hardest. It took me longer to learn it. After I learned it I could get on to the last one easier. The pair of dimmest ones is correct for the last, while the most space between, the most difference in intensity, was first."

No. 13. At first attempted the subjective attitude. Described feelings and impressions. He said, "I'm not attempting to reason. I'm in a receptive attitude. I feel this light will light. I'll try it. Well, it didn't light. I am disappointed." Describes disappointment in terms of feeling tone, *etc.* Later he tried memory. At B. 7 he asked, "Am I giving you any introspections that are good? It's all feeling, not reason." (Later) "I'm verbalizing." Not until F. 15 does he exclaim, "It's greater difference, the group to the left. Insight floods consciousness. It's not strictly phenomenal. It's partly reasoned out. I have a

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feeling that I think I've solved it. I see where I made my mistake. I was more interested in my own introspections. I was biased, but the solution came as a sudden flash. I took a passive receptive rather than an active striving attitude. That fooled me." L.S.—" There's a new problem here." H. 18—(solution) " It's the pair opposite the two bright ones. It's the dimmest pair. (Final statement) " It's a total configuration made up of two natural parts or pairs. The solution came as a sudden flash. I saw the solution and the past course did not enter in so far as I can see now."

No. 14. (An old gentleman.) At D. 14, a sigh indicated the presentation of the even pair. No response. At D. 20, (solution) " I was working on the pair with the greatest difference." L.S.—G. 14, (solution) " The pair nearest opaque brings the correct response, the pair that has the least amount of light. (Final statement) " I questioned the manipulation at first on this problem. It was quite a while before I tried to study out the new solution. When it came it seemed to come all at once, suddenly. It's a matter of judgment. I had a hunch before that the solution was correct. It is really inexplainable. It may be a feeling or result of a feeling. When you changed the problem I questioned the manipulation quite a while before I tried to study out a new way. The solutions came at once, suddenly. I had had a sort of hunch all along that I was getting it. It's really inexplainable."

No. 15. (Preliminary statement) After trying memory schemes and brightest single member, and darkest member, said, " I'm starting all over " and at C. 5, said, " The one that has the highest and lowest in the pair." He did not keep responding correctly. Later, " I have an idea I can't express." At C. 19, (solution) " It's the pair with the different values or the greatest range." L.S. At E. 2, " It isn't the same problem." At F. 2, " No principle occurs to me yet. I've tried greatest and smallest range." At F. 17, (solution) " The darker of the two pairs, taking the pair as a whole." (Final statement) "At first it struck me as a whole situation, then as four lights with differences in values and later the two pairs was thought of and finally equalities and inequalities as containing a problem to be solved. Each situation

seemed new until insight entered. I thought the bright side pulled at first."

No. 16. Preliminary observations: "I see four circular lights. Nothing else in particular." This subject adopted a complex memory system and after the third time through had discovered the repetition of various patterns. His near solution of the problem after the fifth time through was as follows: "The light varies inversely. If two and four counting from the south are bright, the south lights. If the second from the north is bright the north lights. If the two on each side are equal, no light. If the second from the south is bright, that side lights, *etc.*" The final solution came when the subject discarded the memory system and adopted the problem-solving attitude. His memory system was a hindrance rather than a help to the complete solution. This subject was called away and did not complete the training series or the L.S. series.

No. 17. (Preliminary observations) "I see four lights arranged in two pairs." Later, "It looks like relationship between the lights is the problem." G.D.—(upon solution) "It's a bright one and a dark one that is right and not the equal ones." L.S.—The first presentation brought an incorrect response and the subject exclaimed, "What's that? That changes the thing. Is it supposed to be the same problem?" (Upon solution) "When the pair that is dimmest needs the little light to make them equal to the other pair. Is that it?"

No. 18. (Preliminary observations) "I see little lights. Four lights with black space around. There are two groups of two. (After lights were switched off) "The lights are out, but I can still see where the lights were." (After-image) After surveying the first presentation, "I'd like to touch one of the buttons, may I?" At A. 11, "I've been guessing so far." G.D.—(solution) "The light is where there is the greatest contrast." L.S.—C. 5, "The greatest difference is on the left, but it lights on the right." C. 9, "I've tried least difference, but it doesn't work." C. 13, "I've gone back to greatest difference." C. 20, "Except for exceptions the first principle works. There must be a new plan though." (Solution statement) "It seems the light flashes where

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the two dimmest ones are. I discovered it on the one with the equality in the pairs the last time for sure." (Final general statement) "It came all at once that it was the intensity. That was the way you decided. It gradually dawned on me that it took two lights rather than one. It is a problem to find out how soon it takes a person to recognize the significance of the lights. When you changed the problem you were trying to see how long it would take me to change my habit. The last problem was easier than the first."

No. 19. (Preliminary statement) "I see a group of white spots. There are two and two. There are four altogether. I am curious what it's all about." G.D.—(solution) "When there's a light one and a dark one, I get a light. But I don't get it when they're the same. The first thing I think of is the bright. Contrast comes as a second thought." L.S.—C. 1, "You've changed on me." C. 5, "I'm puzzled. Do my eyes deceive me or have you changed?" C. 12, "Are you consistent all the time. That's what I'm wondering." C. 20, "It seems to be the less intense of the four." D. 8, "It's one dark or two dark ones." D. 9, (solution) "It's the two whose sum-total is less than the other two." (Final statement) "I was afraid I couldn't estimate the lights on account of my eyes."

No. 20. (Preliminary statement) "I see two pairs of lights, all the same. They are grouped in two units. That is noticeable." G.S.—A. 14, "I'm trying to equalize. That's my scheme. The tendency is to increase the weaker side, yet I am pulled toward the stronger." B. 20, (solution) "I've got a new rule. The trend of affairs is to pay more attention to the dissimilar pair regardless of the intensities. I violated the equalizing rule and revised my rule. The dissimilar pair is correct."

No. 21. (Preliminary statement) "I see lights, four lights, four in a row." B. 12, "I've lost my bright idea." G.D.—(solution statement) "It's the bigger ratio of difference." L.S.—C. 1, "Why is that? The biggest degree of difference isn't there. You know it isn't. You've changed your stuff." "Well, now, that's all right again." D. 5, "It's the least ratio." D. 14, "Well, that pair as a pair is the dimmest. It's the pair with

lowest intensity." (Final statement) "The greater difference came, when it came, all at once. The solution of the last problem was more gradual. I made correct responses both times before I realized what made them come right. There was no pleasure in it at first. I was more afraid I wouldn't do it right."

No. 22. (Preliminary statement) "I see four lights, two pairs of eyes." G.D.—A. 17, "I can't understand it yet. I'm curious." C. 18, "Oh, I can't think. Let's see. The right pair is where one is bright and one is dim." D. 4, "It's the brightest and the dimmest together." L.S.—E. 1, "Well, it looks like that ought to be the other way." E. 9, "I'm working on the basis of the dimmest one." E. 15, "The lowest pair, is that it?" (Final statement) "The brightest light seemed to pull for my response. Sometimes I tried too quickly. I saw the pairs more distinctly than I saw the four altogether."

No. 23. Made no preliminary statement. G.D.—A. 3, "I'm curious and bemuddled, but the light lights above the dimmest." A. 4, "That sort of put a jolt in what I'd thought." (Solution statement) "A bright one and a dim one must be on the same side. It's the uneven pair. When there's greater contrast." L.S.—D. 1, "I'm suspicious that my rule has gone blooie." D. 5, "My rule doesn't hold. I've got to figure up a new rule." D. 9, "It's the ones with the same intensity. You are using a different set now." D. 11, "It's always the one to the right. Is that it?" D. 17, "It's the odd one." E. 2, (solution) "It's the pair that is less bright." No final statement.

No. 24. A little girl of seven years, second grade, leading her class, was used for this experiment. She solved the problems. Her introspections are so interesting that we record them all.

(Preliminary statement) "I see eyes. They are every shape and there are four eyes, two on one side and two on the other." G.D.—A. 1, "There's one dark and one light on one side and one dark and one light on the other, but one on this side is darker than the one on this side." (She was pointing.) She responded after 44 seconds by pressing side which lighted, and without demonstration. A. 3, "The opposite side lights." A. 10, "It had a bigger light than the others did. This is a good game." A. 13, "That

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one hasn't any light in one of the lights, has it?" A. 14, "I don't get any light from either side of the eyes. The eyes don't go on on one side very much." A. 16, "I missed that one, but it's fun anyway." (Holds key down while waiting for next presentation.) A. 18, "I don't know why I press the side I do." A. 19, "I pressed because one was light and one was dark. The dark one on this side that was right last time." B. 14, "Neither will go on, why is that?" B. 20, "I pressed the darkest one." C. 1, (Made a mistake and laughs.) C. 20, "I know a way." (Presses both keys simultaneously.) D. 5, "I can't do it." D. 20, "I just press. I haven't any way." E. 14, (The equal pairs.) "I've seen that one three times. It won't light either side." E. 15, (Begins to sing a school song to herself.) F. 14, "Aw, I've seen that one before." F. 20, (She had been correct since F. 12.) (solution) "The light and the dark. The darkest and the lightest go together. Maybe both are light and dark, then the lightest and the darkest. First I thought it was the light one, and then the dark one. I found it wasn't, so I changed to this way and it works." L.S.—G. 5, "I didn't get it." G. 14, "I've seen that before. Well, what makes it light? The two darks lit." (This was the one with the equal pairs.) G. 20, (solution) "I'm pressing the darker side. I started with a dark and a light and now I press two darks. You changed on me a while ago, didn't you?" (Final statement) "Well, first I pressed a dark and a light, and then when you changed it I pressed two darks, or something like that, I don't know. That's all I have to say."

No. 25. A little boy, aged four, pre-school, was tried. He did not solve the problem. After 80 presentations he became tired and frightened in the dark room and the attempt was abandoned. His curve is a series of plateaus, with a ratio of 48 correct to 32 incorrect responses. (Preliminary statement) "I see a lot of lights. They are pretty lights." G.D. (after pressing both keys) "I like to do it. What are the round things for that make the lights light up above? What are they for? It's night in here now isn't it? Is it daytime or night time? I think it's night in here anyway, but it's daytime though. I like to play with these little things." After a running series of comments at B. 6, "I

got that one wrong. Well, we can start all over again, can't we?" At C. 10, "I just know which one to press sometimes. Sometimes I know and sometimes I don't know. I'm tired." D. 20, "I'm so tired. I'm too tired to do any more today. I want to go out where it's daytime." (Experiment was discontinued. We desired to see if this subject's performance would be a pure chance curve. He showed some intelligent responses and was above chance although no solution or insightful behavior definitely emerged.)

No. 26. (Preliminary statement) "I see white lights. Four lights in a row, arranged in pairs. They seem equal. I don't know what it's all about. I'm curious and timid." G.D.—A. 7, "I was wondering if you were trying to see which hand I used the most." A. 20, "I have no ideas yet." B. 11, "I tried the brightest light, that wasn't it." B. 19, "I'm trying addition, the dimmest pair." D. 4, (solution) "It's the side that has the greatest difference." L.S.—E. 1, "That one seems wrong." E. 7, "I'm trying least difference." E. 20, "It's the dimmest pair." (Final statement) "The correct solutions came slowly, gradually dawned on me. When it came I felt satisfaction. I thought when you changed that I could catch on to the new way easier than the old, and I think I did."

No. 27. (Preliminary statement) "I see a black space with lights in the shape of circles and arranged in pairs. I'm curious and wondering." G.D.—(solution) "Oh it's to press the bright and the dim side." The subject was called away and did not return to complete the experiment.

No. 28. (Preliminary statement) "I see four lights with two specks above and between. The lights are like eyes on your face, two pairs, two and two." G.D.—(solution) "The side I choose is unequal, the most unequal division of light." L.S.—C. 1, "You have changed it." C. 2, "I have gone back to my old course. You were just doing that to see what I would do." C. 5, "Well, you fooled me again." C. 19, "It's another problem and it's the one with the least light." C. 20, (solution) "It's the least light for the pair." (Final statement) "Solutions came gradually at first, then became sure suddenly."

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No. 29. (Preliminary statement) "I see a blackboard with four lighted circles and two pairs of eyes. I'm wondering what it is all about." G.D.—A. 1, "I feel like a telegraph operator." A. 4, "I'm right-handed and use the right hand more than the left." A. 9, "I make quick and impulsive reactions. I probably make more mistakes that way." A. 10, "I press the dimmer pair." A. 16, "I'm trying the brightest ones." A. 20, "I'm trying the dimmest one." B. 18, (solution) "It's the side with less equality in intensity. I had a hunch in back of my mind. The solution was gradual." L.S.—C. 6, "I need to get more hunches, I guess." C. 7, "I'm trying the ones more nearly equal" (lesser difference). C. 8, "That does not work." C. 13, (solution) "Those dim ones bring the light." (Final statement) "The solution came as a hunch, growing, and then broke in with the correct idea. I was timid at first, but later became so much interested that I forgot timidity."

No. 30. (Preliminary statement) "I see a black screen with two pairs of circular lights. There are two keys here on the table in front of me. There are four lights up there. I am curious and a bit anxious." G.D.—A. 7, "The brightest light gives the little light." A. 20, "The brightest light does not work in all cases." B. 4, "I think now that the light will appear above one bright and one dim rather than a pair where they are both bright or dim." C. 20, (solution) "Greater difference solves it." L.S.—D. 1, "Say, there's greater difference over here." D. 5, "That upsets the whole works." D. 9, "I hate to tell you that I don't think there's anything to it now." D. 15, "Some more of that stuff. I don't know what to press now, except to go by the old theory." E. 1, "Say, can you tell me, is there another theory that I should find?" E. 12, (solution) "The dim side gives the light." E. 20, "It's the dimmer side, that's final." No final statement.

VI. Discussion of Results

1. The Genesis of Insight. From three sources of evidence: (1) the introspections of the observers, (2) observation of their behavior, and (3) the nature of their learning curves, it is pos-

sible to demonstrate three outstanding stages in the genesis of insight. The experimental situation including the arrangement of the lights is first perceived in its entirety but in an undifferentiated fashion. There is a group of lights seen against a black field or ground, then the four lights group themselves into pairs. As soon as the presentations appear the light-situation is reduced to its simplest terms and each light is judged for its intensity in relation to the other three. This original differentiation leads the subject to employ as a possible clue in solving the problem the relatively isolated property of a single light in relation to the other three. Accordingly, he attempts as his first method of solution to select as the correct side that which involves the brightest or the dimmest light. At this stage in the development of insight, the choice of the brightest or dimmest light failing to work, the subject will adopt a plan of the same general type such as a position cue occurring in a rhythm: Two correct choices at the right, one on the left, *etc.*

But the observer soon finds that he is unsuccessful. There then evolves the second main stage in the development of insight, namely, that somehow the relationship in one pair differs from the relationship in the other. This realization is always invariably vague and undifferentiated at first, in fact, it appears at the outset as a *hunch* or feeling which cannot be articulated, but is sufficient, if it is correct, to guide the observer through several choices before he is able to say definitely what scheme he is following. The first realization of a relationship is not always the correct one and, therefore, is abandoned sooner or later. As analysis of the alternative proceeds, the subject's choices become increasingly correct. Frequently the subject will make five or six correct choices with his plan in mind so undifferentiated that he is unable completely to make voluntary and accurate use of it, and will momentarily abandon it for another only to return with the mere feeling that it was correct. Then it is definitely realized as a 'hunch' to follow, and from then on the responses are errorless. Occasionally this final stage in the emergence of insight does not develop explicitly enough to articulate in words for several repetitions to come, although the correctness has come

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with a flash. Usually, however, the correct relationship is definitely perceived at the time this flash of insight emerges.

When the experimenter changed the problem, unknown to the subject, from greater difference to lesser summation, the learner frequently insisted that something had gone wrong with the apparatus and in various ways resisted a change in procedure. When it dawned on him that the experimenter had deliberately changed the combination he discarded the previous solution and as a rule almost at once discovered the new combination. The steps in this process were identical with those of the original emergence of insight save for the fact that they were much more attenuated.

In terms of number of trials the emergence of full insight may be either rapid or slow, abrupt or gradual, simple or complex, and depends upon the difficulty of the problem for the observer, and upon his attitude. The correlation of the rapidity of the emergence of this insight with the intelligence quotient of the observer remains a problem for further experimentation.

Just what relation this insight may have to the possession of the ability to discover and invent is a most alluring field. Our experimentation is fruitful of a host of problems awaiting solution and provides the technique of attack upon many of them.

It remains to discover whether a subject's insight can be trained, whether some intelligent subjects lack it in large measure, whether it is closely related to inventive ability, just what is its relation to various sense organs, whether the amount of transfer can be largely increased over a period of time, just what effect the removal of the goals (signal lights) from certain presentations would have, just what part the resolution of tension may be discovered to have, what the relation of insight may be to the so-called process of "conditioning", and many other facts.

In our experiment relative judgments have been carried further than heretofore into the field of relationships between relationships which is a new field of experimentation. We have developed a new technique.

We find, in general, the same principles operating which have been discovered to hold in the simpler relational judgments.

Köhler's statement (13, 371) that "A total field would be experienced without insight, if all its several states, wholes, attitudes, etc., were simply given as a pattern, in which none was felt directly to depend upon any other and none to determine any other", seems to be the zero point from which we proceed to full insight in our experiment. Helson's summary (7, 55) taken from Wertheimer (19) states that "Insight depends upon the ability to break up existing configurational structures and to make fruitful transpositions from one configuration to another" and seems to apply to the process of analysis of our subjects.

It is important to note that conventional theories of learning by trial and error, frequency, recency, and effect, will in no way explain the results of this investigation. First, the discovery of the correct solution could not have been a combination of elements existing in previous efforts because a certain solution was either totally wrong or totally right. The new could not have been a combination of the old. Second, associating one light with another through the formation of bonds could not have resulted in progress because the light of a given intensity when in one combination belonged to the correct pair and when in another to the wrong pair. For example, consider the combinations, 3:2 and 5:3, the size of the number indicating the brightness of the light with 1 the dimmest. Number 3, when on the left, belongs to an incorrect pair, but to a correct pair, on the right, in the problem of greater difference. In the next combination, which might be 1:4 and 5:3, the 5 and 3 belong to the incorrect pair. There is no possible way of solving the problem, therefore, by associating a given light in any particular way with its neighbors. The response must be configurational, that is, made to each light in its relationship to the total pattern, and the relationship perceived must be discovered each time as a new problem because the range between the lights and the range of the difference between the pairs are constantly shifting. No better proof could be obtained of the fact that learning is a matter of discovery, of making a new response each time.

2. *A New Plotting Method.* By controlling the order in which the combinations of lights are presented to the learner, and by

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plotting the learner's choices successively on cross-section paper, going up one step and to the right for a successful choice and going down one step and to the right for an incorrect choice, it can be determined from the pattern of the curve whether the learner is making his decisions at random or precisely what scheme he is endeavoring to follow (see Fig. 2). There are several possible schemes which the learner may attempt to follow, such as lesser difference and lesser summation, side of the brightest light or side of the dimmest light, and so on, the following of which would reveal its own unique pattern of right and wrong choices on the curve. The curve of random choices would be a horizontal line. The curve for correct choices of greater difference would be a straight line at a 45-degree angle from the random choice line. Thus it can be seen that the plotting method makes unnecessary any recourse to introspective data, for an inspection of the curve informs the experimenter what is going on in the observer's 'mind' at any one time with a surprising degree of accuracy. It is suggested that a method of this sort would be extremely valuable in animal experimentation.

3. Reaction-Time and its Significance. It was discovered that all subjects began the experiment with long responses during a period of initial survey of the problem. The reaction-times then rapidly dropped to average or near average. Just before each solution there was a peak indicating 'initial delay.' Had the experimenter known enough to watch for it, this pause, before insight, would have given the clue to the moment of full insight in almost every case. This reaction-time curve, while not crucial to the experiment, is a valuable addition to the 'performance picture'.

4. Transfer. By our use of this term we do not mean transfer of 'identical elements' because the problem is definitely one of transposition and relative judgments. The raising or lowering of the four light intensities, leaving the relationship the same, presents a constant relation but a different set of 'elements'.

We find a 'transfer effect' as Ruger did. It is a phenomenon of the learning process which Wheeler (20) states as occurring

when there is " similarity of content ", " similarity of methods ", or " similar attitudes ".

It is obvious that these are conditions under which transfer will take place but do not imply the existence of identical elements. The constant factor is not a discrete entity which shifts from one situation to another, but on the contrary, is evidence of an original, general insight into the problem-situation which itself differentiates with respect to the stimulus-patterns in question. The differentiations are, in each case, an integral part of the original, undifferentiated pattern, and issued from it. They were not discrete experiences of separate origin later to be combined with the ' common element ' by experiencing them together. The fallacy of the ' common element ' theory, or of any associationistic theory, is at once apparent when one reflects that even if such an entity existed it would be of no use to the learner because in every new situation it would have to be bonded with the ' uncommon elements ' before the two would function together. Transfer could not possibly take place, therefore, because in every new situation the relevance of a ' common element ' would not be apparent until after it had been learned through a trial and error procedure. No matter how many times the ' common element ' had been used the learner would be thrown back to a totally strange situation each time a new feature of the problem-situation revealed itself. On the other hand, the configurational principle does not, by definition, raise such a problem. The first response is to a total situation and subsequent responses are expansions and differentiations following after the original one. Transfer then becomes a matter of duplicating a response in a new situation and differentiating it with respect to the particular features of that situation. The process is insightful, not associational.

VII. Conclusions

This experiment would seem to justify the following results:

1. Insightful behavior can be represented by a performance curve showing an upward drift. This drift is due to the emergence of a " hunch " or unanalyzed experience which grows clearer

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and clearer in the form of a differentiation process. Finally full insight emerges like the emergence of figure out of ground.

2. The light intensities may be shifted within the limits of clearness and if the ratio remains the same, the experiment is unchanged, showing transposition and satisfying this criterion of insight.

3. This experiment shows transfer in the solution of problems of relationships.

4. There is a pause or period of deliberation just previous to full insight.

5. Neither too rapid nor too deliberate responses are conducive to the early emergence of full insight.

6. The technique of this experiment gives promise as an accurate approach to the measurement of the insight of the subject.

7. As this experiment can be made entirely non-verbal, it is adapted to the measurement of races, ages, and types of both human and animal organisms.

Finally, we see the possibility of constructing a test using relative judgments between pairs of light intensities which will prove most valuable, in the determination of the Intelligence Quotient, in measuring insight, and in giving data upon the emotional and attitudinal behavior of both normal and abnormal subjects.

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AN ANALYSIS OF THE RELATIONSHIP BETWEEN TACTUAL AND VISUAL PERCEPTION[1]

by

THOMAS D. CUTSFORTH

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I. HISTORY

The history of psychology has harbored but few doubts regarding the qualitative specificity of sensations and the discreteness of sensations supposedly conditioned exclusively by different

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sense organs. Classifications of sensory modalities have been based altogether upon corresponding sense organs and sensory qualities. The result has been that the history of psychology is marked by much greater success in the process of reducing sensory consciousness into small sensory units, than in erecting a theory of how these same units become organized into a continuous, dynamic consciousness.

Aristotle, in his *Sensus Communis,* made a mystical attempt to explain how sensory experiences regarded as discrete entities were utilized in a conscious whole. However, his doctrine of the 'common sense' did not truly account for structural unity, and only provided a questionable functional whole in which the sensory parts were incorporated.

The doctrine of association lent itself well to the concept of the 'common sense' with the result that it was not until the appearance of Hagen's work (1) that a plausible dissent was heard against the partite sensory composition of consciousness. Hagen suggested that the normal consciousness was visual and that all perceptions were made in terms of this modality.

The doctrine of local signs, of Lotze, and the methodology of Fechner, which was continued by Wundt, added a great superfluity of proof to the belief in discrete sensory qualities. It was not until the time of Pillsbury (2), Judd (3), Washburn (4) and Parrish (5) that any evidence to the contrary was produced. These four studies failed entirely by using different methods to separate visual processes from those of touch and kinaesthesis.

All during the nineteenth century cases of synaesthesia had been reported but since they were described and explained in the terms of associationism which assumed that the synaesthetic sensation was a secondary process accompanying the primary sensation, the validity of the primary sensation was not challenged.

Stratton (6), in his experiment on the effects of retinal inversion, found that the perceptions primarily of touch and kinaesthesis were inextricably bound up with those of vision. His results furnish more evidence than he himself saw. However, through his adherence to the doctrines of local sign and association, he was unable to make use of these valuable observations.

The unemphasized results of Stratton were confirmed in the work of Brown (7) and Wooster (8).

Benussi (9), in 1913, was able to demonstrate apparent movement in the field of touch. Later, Burtt (10) was able to verify Korte's laws in the tactual modality. Since then numerous studies have been made which emphasize different phases of apparent movement. In all of these instances the importance of visual processes for apparent movement can hardly be ignored.

Wheeler and Cutsforth (11) have shown that synaesthesia does not consist of a dual process in which the 'secondary sensory' experience is an associative concomitant of the 'primary sensation'. The synaesthetic process is all that exists in the experience and without it no experience would be possible. The undifferentiated 'parent process' is all that exists of the primary sensation and that does not even possess awareness of quality. It is merely a cognitive reference, a 'pretemporal' awareness.

In 1920 Gelb and Goldstein (12) reported the case of a soldier suffering from a wound in the occipital region. The patient lacked visual memory and complex visual perceptions, and at the same time, failed to localize tactual experience when blindfolded, except as he made use of bodily movement.

In 1929, Förster (13) reported a study on mirror learning in which it was shown that motor learning depends on visual processes.

These studies, and many others, raise the question whether, after all, the orthodox conception of the sensory field, as one composed of discrete sense modalities, is correct. If the *Gestalt* theory is correct the orthodox conception is wrong, and a strikingly different view from that formerly prevailing must be held. The issue, specifically, is this: Do full-fledged perceptions develop independently in each modality, and are they to be explained in terms of sensory elements? It was in the interest of adding to the solution of this problem that the present study was undertaken of tactual-visual perception.

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II. The Problem

The problem of whether the sensory field can legitimately be divided into discrete modalities such as visual, auditory, tactual, and so on, each qualitatively and functionally distinct from the other, is a problem of inter-modality relationships. The method by which it was attacked in this investigation consisted in general of requiring that a perception, supposedly originating and developing in one modality, be reproduced or duplicated in another. The two modalities selected were the visual and tactual-kinaesthetic, and the specific problem with which this study was concerned was the analysis and description of the mental processes involved in estimating size tactually and kinaesthetically and of reproducing that size visually. It was hoped that this procedure, which demanded a shift from one so-called sense modality to another, would furnish some cues regarding their dependence or lack of dependence. Means were adopted, as far as possible, of securing quantitative data of statistical reliability.

III. Preliminary Experiments

Prior to the adoption of the procedure finally employed, four preliminary methods and a total of fifty-one subjects were used. Although the preliminary studies produced quantities of positive material and furnished considerable insight into the nature of the problem it was necessary to abandon each, successively, due to some inherent defect within the method. All the preliminary methods employed concrete stimuli to be judged in relation to other concrete objects with the result that it was impossible to control the factor of learning a range or series of standards. This learning caused judgments to be rendered in terms of the entire series or in terms of previous judgments, and unnecessarily complicated the quantitative data.

IV. Apparatus

The apparatus used for the purpose of securing visual judgments of tactual size consisted of a semi-horizontal hand screen and a vertical board on the front of which was an adjustable

diaphragm. (See Fig. 1.) The hand screen was made of one-half inch pine board ten by twenty-eight inches. It was mounted six inches above the end of a laboratory table upon two one-half inch pine boards ten by six inches. The front opening was

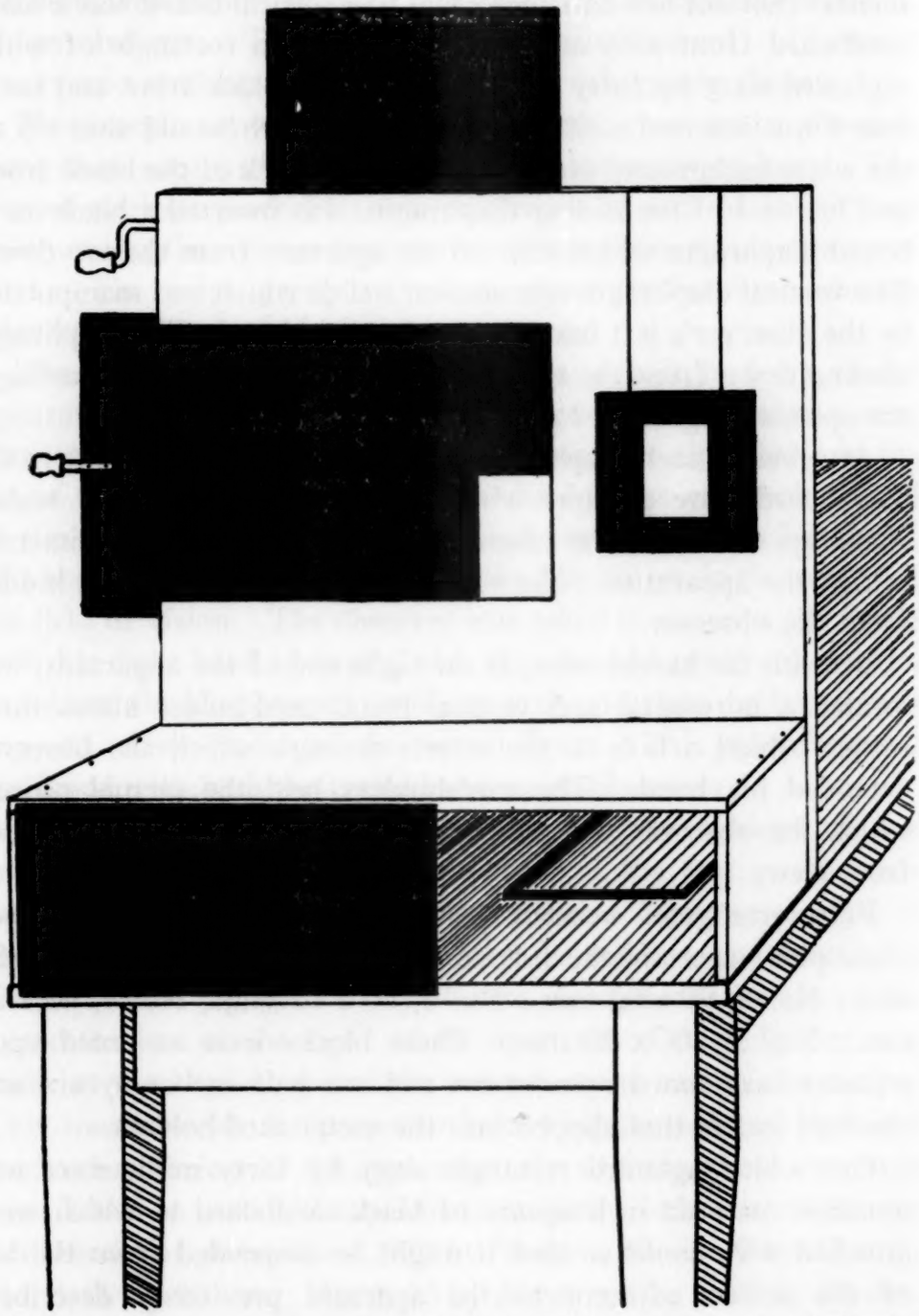

FIG. 1. Diagram of Apparatus to Show the Relation of Tactual and Visual Perception.

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covered, with the exception of ten inches at the right, by a black cloth curtain hung from the edge of the screen. At the back edge of the board screen mounted on rods and clamped to the table, was the vertical board, one-half inch thick by twenty-eight by ten inches. Set out one-half inch from this vertical board was a black cardboard front with an aperture exposing a rectangle of white tagboard sixty by forty mm. Between the black front and back-board was inserted a sliding diaphragm which would shut off all the white background from the left. Also back of the black front, and in front of the sliding diaphragm, was inserted a black card-board diaphragm which shut off the aperture from the top down. The vertical diaphragm operated on a slide which was manipulated by the observer's left hand in trombone fashion. The diaphragm coming down from the top was mounted upon a sliding carriage, manipulated higher or lower by a crank, also at the left.

Attached to each diaphragm and extending through slots in the back-board were pointers which moved along millimeter scales. Readings could thus be taken off the scales by the experimenter behind the apparatus. The scales and experimenter were hidden from the observer.

Beneath the hand-screen, at the right end of the apparatus, was located a horizontal and vertical metal card-holder about three inches behind a hole in the screen through which the observer extended his hand. The card-holders held the tactual objects which the observer was to explore with his right hand hidden from view.

Five rectangular wooden figures were cut from one-half inch triple pine veneer in the following dimensions: No. 1, 120 x 80 mm.; No. 2, 90 x 60 mm.; No. 3, 60 x 40 mm.; No. 4, 45 x 30 mm.; No. 5, 30 x 20 mm. These blocks were mounted upon separate card-board squares six and one-half inches by six and one-half inches that slipped into the metal card-holders.

One white tagboard rectangle sixty by forty millimeters was mounted on a six-inch square of black cardboard to which were attached wire hooks so that it might be suspended from the top of the screen adjacent to the aperture previously described. The purpose of the visual rectangle will be described in the text.

V. Main Experiments—Method

The investigation proper was divided into two parts. The first was performed with a group of ten trained observers made up of ten male members of the staff and graduates from the department of psychology. The second group consisted of 120 naïve observers—students from the elementary laboratory classes.

The experiment was performed in a dark room under the constant illumination of a one-hundred-watt incandescent lamp. The trained subjects made fifty-two judgments at each of six sittings held not less than seven days apart and not more than twenty-one days. The naïve group served as observers but once, during which sitting each made fifteen judgments.

The observer was seated in an ordinary chair in front of the apparatus with the adjustable diaphragm, so that it was convenient and comfortable for him to employ his right hand in the act of examining the tactual objects held in the card-holder, and at the same time manipulate the diaphragms with his left hand. His position brought the center of the diaphragm in the center of the field of vision. The observer was asked to examine the figure with his right hand tactually, and when he had perceived its size, to adjust the diaphragms until an area of white tagboard was exposed which duplicated the tactual figure. This procedure was employed with both the trained and naïve observers.

The trained observers were divided into two groups of five each. At the first sitting the members of the first group made two judgments which were purely visual. They were asked to reproduce upon the diaphragm the perceived size and form of a white piece of tagboard 60 by 40 mm., hung from the top of the apparatus just at the right of the aperture. One judgment was made at the beginning and the second at the end of the sitting. This was done for the purpose of checking the accuracy with the mechanical devices of the apparatus. In addition, these observers were asked to make 10 reproductions each of the tactual figures in the order as given, No. 1, 120 by 80 mm.; No. 2, 90 by 60 mm.; No. 3, 60 by 40 mm.; No. 4, 45 by 30 mm.; No. 5, 30 by 20 mm. During the first sitting of this group the figures were presented

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in a horizontal position with the long axes running north and south, map-wise. Also, at the first sitting, these observers perceived the tactual figure by the method of 'passive touch', that is, of placing the hand and fingers upon the figure without making exploratory movements. This will be called the Horizontal Passive procedure (H.P.).

In the second sitting of this group the observers were permitted exploratory movements of the index finger confined to the edge of the figure, the Horizontal Active (H.A.) procedure. On the third sitting the observer was permitted to employ any method of tactual-motor examination which suited him, the Horizontal Voluntary (H.V.) procedure.

On the fourth sitting the figure was changed to a vertical position with the long axis of the figure running up and down. On the fourth, fifth and sixth sittings the methods of tactual perception were repeated in order as in the horizontal position. These are to be called the Vertical Passive (V.P.), Vertical Active (V.A.), and Vertical Voluntary (V.V.) methods.

With the second group of five trained observers the procedure varied only in that the first sitting started the first of the vertical positions and the fourth started the first of the horizontal positions. Total judgments in all, by trained observers, 3,120, 50 judgments covering the 5 figures in each of 3 procedures, within two sets of positions of the figures. This number included the visual judgments.

The one hundred and twenty naïve subjects were divided into four groups of thirty. Each group made the two visual judgments as before, using the white visual rectangle; and each judged two series of five rectangles in one of the four methods, H.P., H.A., V.P., and V.A. Group one made their judgments with the tactual objects in a horizontal position employing the passive method of tactual perception (H.P.). The second group of thirty observers employed the horizontal position of the tactual object using active finger movement of the index finger about the edges of the figures (H.A.). The third group of thirty observers perceived their tactual figures in a vertical position by the static hand method (V.P.), and the fourth group of thirty observers

also employed the vertical position of figures, but with exploratory movement of the index finger (V.A.). Total number of judgments by untrained observers, 2,040, 17 by each of 120 observers, 30 observers for each of the 4 methods used. Total number of judgments for the entire main experiment, 5,160.

VI. Results

1. Judgments of Visual Size. The ranges of judgments of height and width by both trained and untrained subjects demonstrate a surprising inaccuracy in matching one visual size with another visual size. The curves of distribution conclusively show the extent of inaccuracy in these judgments both for trained and untrained observers. The distribution of judgments for height, in case of the trained observers, extends from 55 to 67 mm., a scattering of 12 mm., or 20 per cent of the standard height. The mode occurs at 59 which is one point below standard height. The untrained observers scattered their judgments of height still further by extending the range from 50 to 68, a range of 30 per cent of the height. The judgments of height for the untrained observers form themselves into a bimodal distribution with the points of most frequent judgments falling at 56 and 60.

In the judgment of width, the trained observers scattered out over a smaller range running from 37 to 47, with a mode at 42. The range, which represents 25 per cent of the standard width, *falls for the most part above the standard.* The untrained observers scattered their judgments over a range, from 33 to 49, which is equal to 40 per cent of the standard width. The mode occurs at the same point as does the width of the standard but a larger part of the judgments fall below this point. An inspection of the curves shows that the trained observers are prone both in their judgments of height and width to over-judge the standard, and the untrained observers to under-judge the standard.

2. The Discrepancy Between Sight and Touch. A large discrepancy was found to exist between the tactually perceived standard and the matched visual equivalent in the judgments of all the subjects made in all the different positions, with all the differ-

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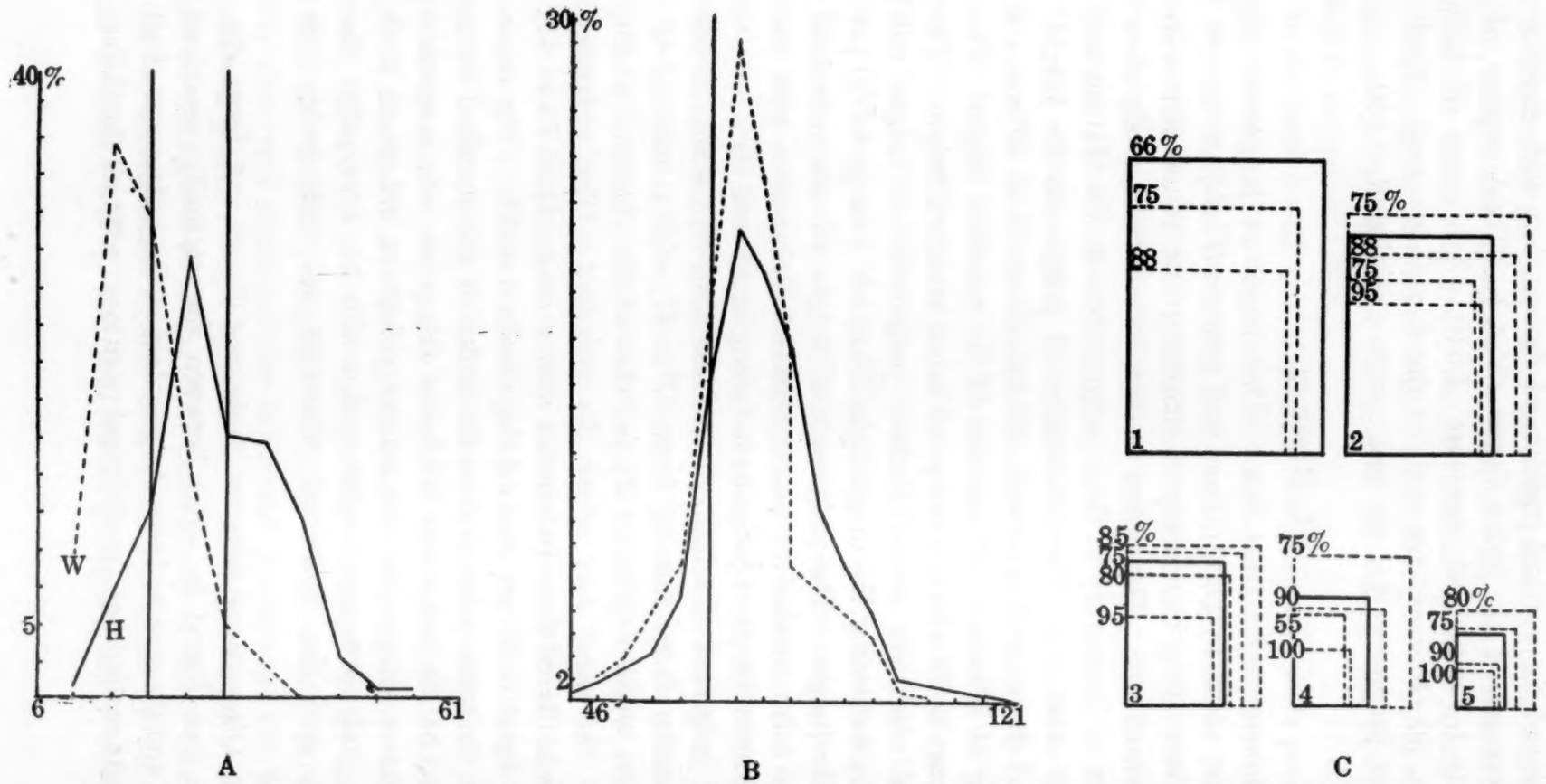

FIG. 2. A. Judgments by Per Cent. Block V. All Methods. W, Width; H, Height. Abscissa, Scale in Millimeters. Vertical Solid Lines Represent Dimensions of Block, 20 mm. and 30 mm. B. Distribution of Squaring Proportions. All Subjects and Methods. Solid Line, Untrained; Dashed Line, Trained. Abscissa, Arbitrary Scale. Solid Line Represents Ratio of W and H, Actual Stimuli. C. Squaring Judgments. Numbers, Per Cent of Squaring. Solid Lines, Actual Stimuli.

ent methods employed, and with all the five stimuli. Under-judgments of the tactual standard were made to the extent of 44 per cent of its size, and over-judgments of the standard ran to 47 per cent, with an average discrepancy running as high as plus or minus 12 per cent for certain of the stimuli. The ranges of distribution are modified by the different positions, methods and standards employed. (Fig. 2A shows underestimation of W and H.)

3. The Effect of Position on the Discrepancy Between Sight and Touch. The horizontal position is conducive to more accurate judgments than the vertical position. The different effects of the two positions can be seen from Tables II and III. Table III shows the discrepancies for height and width for the horizontal and vertical positions separately. These differences do not remain constant for all methods and all sizes, and also vary between observers. The difference between the horizontal and vertical positions and between trained and untrained observers is revealed not only in the two ranges of judgments which differ in extent, but also in the places along the distribution where the greatest number of judgments fall.

4. Effect of Passive and Active Exploration on the Discrepancy Between Sight and Touch. The two methods of examination of the tactual standards—passive, and active—produce different ranges of distributions of judgments. The effect of the two methods is displayed in Tables II and III. In Table III the extent of the discrepancy between the actual tactual standard and the matched visual size is given. The results show that the active method reduces the extent of over-judgments and increases the extent of under-judgments in both the height and width. That is, it shifts the range of distribution farther below the tactual standard. This effect becomes less apparent on the smaller blocks, and is less apparent for naïve than for trained observers.

The effect of movement upon tactual perception would indicate that tactual space was less apparent during movement than when the hand was in a passive state. The fact that the trained observers exaggerated this tendency as compared with the untrained observers would indicate that the trained observers

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possessed perceptual equivalents for a less amount of the finger movement than did the untrained observers. The trained observers, also, moved more slowly than the naïve.

It is not to be contended that it is possible to separate entirely the effects of the combined influences of position and movement. It can be seen that passive judgments made from a horizontal position are distinctly different from those passive judgments made in a vertical position. *But, each of the two conditions in combination produce relationships which neither can be held responsible for separately.*

5. Influence of Size on Discrepancy Between Sight and Touch. Size of block exerts an influence upon judgments of tactual size. (Table I.) The chief tendency is to over-judge the smaller sizes more than the larger sizes. This holds throughout for all the judgments by all subjects using the different positions and methods. The inter-relating effects of these conditions can be seen by an inspection of Fig. 2, C. Conversely, the large sizes are underestimated the most. Naïve observers are slightly less affected by difference in size than are the trained observers. It is interesting to note that the relative distortions of blocks two, three, and four are about the same, while the extremes, one and five, show the extreme distortions.

6. Symmetry in Purely Visual Judgments. There is a tendency to perceive visually, a vertical rectangular figure of the proportion of three to two in the more symmetrical relationship of a one to one proportion. The importance of this tendency is still more significant in actual perception of form and will be discussed separately in a special section. However, the suggestion may be made here that the perceptions of visual proportion and form-relationship not only include the perception of form but also the perception of *size* as well. *Size, of necessity, is a perceptual whole that cannot be constructed from separate judgments of height and width.*

7. Symmetry in Tactual-Visual Perception. A tendency toward symmetry was found in 78 per cent of all judgments made from tactual forms. Note that each stimulus-figure possessed the height-width ratio of 3 to 2. Therefore, when the

height has been reduced 66 per cent, the width remaining constant, a square has been produced. For the sake of convenience the number 66 was chosen to indicate the per cent of approximation to a square represented by a rectangle of 3–2 proportions; a perfect square being indicated by 100 per cent. Numbers below 66 indicate a lengthening and narrowing of the 3–2 proportions, respectively, while figures over 100 represent a shortening and widening of the figure beyond that of square proportions. The distribution ranges from 41 to 148 with 66 representing the standard proportion. (Table II.) The mode of the squaring tendency occurred between 71 and 76. Fig. 2B pictures the ranges of squaring graphically.

8. Effect of Passive and Active Methods on Symmetry. The two methods of tactual exploration of the standard had opposite effects upon the tendency toward symmetry. The untrained observers do less squaring when the form is perceived passively and increase the amount of squaring when movement is employed in making the perception. The trained observers do their greatest amount of squaring in the method of passive exploration and decrease the amount of squaring when movement is employed. This shows clearly that neither method possesses an effect inherent in itself but is associated inextricably with other factors. These results seem to hinge upon the fact that the trained observers were too analytical and lost their perception of proportion, especially when making slow exploratory movements.

9. Effect of Size on Symmetry. The trained observers tend to square the smaller figures more than the larger ones. Any extreme diminishes the squaring. Block three shows the greatest amount of squaring, which would indicate that block three received the combined effects of the trained and untrained. The opposite effects of size upon the two groups of observers would indicate that other and more subtle factors were operating than differences in actual size.

10. Relation of Squaring to Accuracy of Visual-Tactual Judgments. It may be concluded that those conditions which are conducive to accurate judgments of size are also conducive to squaring. These conditions are not constant throughout the

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entire investigation nor do they apply equally to both groups of observers. Already it has been shown that the observer himself is an important and neglected factor among the conditions under which the judgments are formed. The different positions, methods, and sizes of blocks cannot be regarded as separate and distinct conditions of judging as such, but only as separate conditions in relation to the observer's procedure.

The relation of the range of judgments of height and width to the actual height and width shows to what extent the figures are broken up and analyzed, especially by the trained observers. The discrepancies between these judgments and actual height and width of the three blocks, one, three, and five, show how the two factors of accuracy and squaring are related. In block one the average judged height is 74 per cent of actual height, width 94 per cent. In block three the average height is 120 per cent, and width 137 per cent. In block five the average height is 160 per cent, width, 150. In block three accuracy and squaring are at their maximum while in block one both accuracy and squaring are less. Finally, in block five both the accuracy and squaring are still less in virtue of a 50 per cent discrepancy in both height and width.

11. Differences Between Individuals and Groups in Squaring. The tendency toward squaring shows more consistency within individuals than it does between individuals. Like the judgments of size the individuals retained their own consistency under the different conditions although the actual amount of squaring was made greater or less owing to a given condition.

The range of all individuals from the least amount of squaring to the most squaring for all positions and for all blocks was 50.6. The greatest range of any individual in any position was 24.7. The least range was 1.9 for a given position. The least average range for the four methods was 4.7 and the greatest was 16.1. The average for all individuals was 10.0.

12. General Differences Between Trained and Naïve Observers. Visual Judgments. Throughout the presentation of the results there have appeared differences between the group of trained observers and the untrained group. The apparent differences

between these two groups are difficult to describe in quantitative terms. In the following paragraph will be presented the differences between the two groups as shown by the experimental data. No attempt in this section will be made to interpret the differences.

In comparing the two visual forms untrained observers underestimate the standard while the trained observers showed the opposite tendency, that of overestimating the standard. These diverging tendencies were consistent for both height and width.

The trained observers tended to square the visual form more than the untrained observers. In their judgment of tactual standards the untrained observers are more consistent, as shown by higher modes in the curves of distribution. The trained observers give more exaggerated and frequent bimodal distributions.

13. Differential Effect of Position on Trained and Naïve Observers. Table I shows the effect of position upon the two groups of observers. It will be found that the vertical position favors an overestimation of both height and width by the trained observers, while the horizontal position favors overestimation in the untrained observers. The vertical position favors more underestimation of height and width by the trained group of observers although both groups do a great deal of underestimating. In other words, the trained observers do more underestimating in the horizontal position than do the untrained and the difference is increased in the vertical position. The untrained observers make more judgments toward squaring on both the horizontal and vertical positions. In the former position they are in excess of the trained group to the extent of seventy-one judgments and in the latter position to the extent of one hundred and fifty-two judgments.

14. Differential Effect of Method on Trained and Naïve Observers. The active method of exploration supports approximately twice as much squaring as does the passive method. The untrained group does more squaring in both methods than does the trained group, but the greater excess of squaring occurs under the passive method. This would indicate that the two methods have opposite effects on squaring in the two groups of observers.

15. Differential Effect of Size of Block Upon Trained and

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Naïve Observers. The series of five blocks as a whole is underestimated much more by the trained subjects than by the untrained. As the blocks become progressively smaller this difference is increased. A similar trend is found between the two groups in the extent of squaring. The trained observers square the blocks less than the untrained and the difference becomes progressively greater as the blocks become smaller.

It would appear as if squaring and the range of distribution in relation to the standard form are closely related. In both the larger block and the smaller block there occurs a greater breadth in the distribution of judgments and also a less amount of squaring, hence it would seem that the extremes of size destroy both accuracy in judgment and at the same time the tendency toward symmetry. Throughout, the untrained observers are more accurate and make their visual figures more symmetrical. *This fact means that accuracy depends upon squaring, i.e., a perception of proportion, rather than upon an analytical judgment of discrete heights and widths.* The trained observers analyzed the tactual object into height and width, reproducing each separately, and therefore were less accurate than the naïve observer who perceived the tactual object more as a whole in its proportion and reproduced it as a whole.

VII. Qualitative Results from the Judgments of the Blocks

The following are typical unsolicited comments made by observers while sitting for the experiment. "The tactual figure is not straight." "The apparatus isn't large enough to represent the block visually." "The block has an irregular form." "The angles of the block are not right angles." "The blocks appear to be diamond-shaped." "I cannot make the aperture fit the block."

The following are typical reports from trained observers. "The blocks all seem to be the same size with the exception of the small one." "The bigness is not controlled by the size of the block." "The blocks all seem like squares." "The judgment seems wrong but I can't do anything about it." "The blocks seemed awfully big but suddenly seemed to shrink on me." "The

longer I explore it the smaller it becomes." "When comparing the tactual and the visual the tactual shrinks." "When I close my eyes the tactual lengthens." "When I open my eyes and look at the visual aperture, it swells." "The block gets smaller as I put my hand on it." "I don't see how I could possibly have made it so big."

These excerpts show definitely the dearth of criteria with which an observer can make a comparison between a tactually perceived object and a visual one. These criteria depend exclusively upon the fact that the tactual perception is as much visual as it is tactual. No observer could find a single tactual criterion as such enabling him to make his judgment. Hence the discrepancy between the actual sizes of the two figures, the tactual and the visual. The subject found it necessary to construct the tactual figure visually without seeing it before he could make a comparison between it and the actual visual figure.

The following conclusions can be drawn from the introspective data: (1) Tactual perceptions of form are distorted through lack of possible criteria of judgment. (2) Tactual perceptions of size lack definiteness for the same reason. (3) Both tactual form and size are recognized by the observers as being unreliable and without criteria. (4) Apparent movement takes place in tactual-visual perception.

VIII. Apparent Movement Between Tactual and Visual Figure

At the close of the sixth or last sitting each of the trained observers was given a test for tactual apparent movement. The procedure for this consisted in presenting block three in the horizontal position with the instructions previously given for the active method. He was told to examine the figure very carefully about the edges and to adjust the diaphragms so that the visual figure matched in size the perception of the block. When this was accomplished he was instructed, further, to fixate the visual figure in the diaphragm carefully and at the same time to place his hand upon the block in the manner of the passive method. After this was done the observer was asked to report how the two sizes of

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the same figure were reconciled, what the appearance was of the figure in the diaphragm and what the appearance was of the figure under the hand.

Three of the ten observers reported that all changes took place in visual imagery of the hand and of the block under the hand. Two of these three reported that the block under the hand appeared to become larger. One reported that he could *feel* the block get larger during the change, but this was a visual-tactual ' feeling '.

Five of the ten subjects were able to perceive an apparent movement upon the figure in the diaphragm. Also at times some of them would report an enlargement of the visualized block under the hand.

Two of the subjects were able to get no transitional changes in the perceptions of size. They were aware that change in size had occurred but they were not aware of anything until after it had happened.

The following are typical reports of the trained observers. " I visualized my finger movements as I stretched out my hand to place it over the block." " The changes are in the tactual figure visualized in the hand." "A definite visual shrinking took place in the block in my hand. It moved in on all sides at once." " On one side of the visual figure the movement takes place, both as a shortening and as a lengthening of the line. It occurs at the opposite end from that which is fixated. I can produce it on both the vertical and horizontal lines. I must get an actual equality of vividness between the tactual and visual perceptions of the squares before movement will occur." " The movement of the hand appears to correlate perfectly with the visual apparent movement. It functions when the visualized perception of the tactual square, or form, flits up to the visual form on the diaphragm. Then the tactual size is perceived in the apparent movement and when the tactual returns the visual form retracts to the visual size." " The change is very rapid and is not always perceived as movement, but merely as a change that has taken place." " While I am fixating the diaphragm I can see the tactual block shrink. It is projected upon the aperture with its sides coinciding

with the sides of the aperture. The shrinking takes place upon the aperture." "When the tactual object is again perceived, the visual figure increases in size. It changes on all sides in a visual outward movement." "When I grasped the block it became larger. It was a visual swelling of the pressure-pattern in my hand." "With a passive grasp of the block and by shifting my hand-pressure lightly from one side to the other, I can see one side of the visual figure extend in both directions when I fixate the center of the side."

Masses of introspective data like the above may be summarized in the following fashion: (1) Apparent movement may take place on either the tactual or the visual figure as an effort is made to correct a discrepancy between the two perceptions of size. (2) Ordinarily apparent movement involves the shrinking or swelling of the whole figure. (3) With an analytical attitude apparent movement may involve but a single side of the visual figure. (4) Under an analytical attitude the movement may be perceived in a single side, as moving in either direction or as moving in both directions when the side is fixated in the middle. (5) The movement may occur in the form of concrete visual imagery or in highly schematized visual imagery. (6) Under the conditions of this experiment tactual processes as such do not yield apparent movement. The movement is seen, not felt. (7) At no time was an observer, naïve or trained, able to describe tactual form or size in other than visual terms.

IX. Discussion

Since it is possible to demonstrate that touch is incapable of supporting spatial perceptions of size and form, it is necessary to harmonize these findings with theoretical views which may account for such a flagrant violation of the constancy hypothesis. Were it any longer possible to think in terms of specific sensory functions, the condition which we found in our experiment might be described as visual processes having usurped the perceptual functions carried by touch. Any such explanation as this is quite inadequate to describe the total visual nature of tactual experiences in our subjects.

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It is necessary to regard the judgments of our subjects genetically and ask the question if touch has ever been a factor in the tactual perception of spatial size and form. In the development of the infant, visual perceptions in the case of normal eyesight always precede that of spatial tactual perceptions. In other words, spatial relationships at the very first become differentiated and emerge from a visual ground. The space frame of the normal seeing child is what might be described as a synaesthetic visual space frame out of which spatial relationships must be structured. The extent to which the visual ground may be spatially differentiated has not yet been determined, but it has been found that it is sufficient to support so-called tactual apparent movement which was employed by our subjects in relating discrepancies in tactual-visual space.

The congenitally blind, who have never maturated in a visual direction, possess a kinaesthetic ground out of which spatial relationships differentiate. It by necessity carries a much higher subjective or bodily relationship to spatial perceptions than the more objective visual spatial relationships. The extent to which these two spatial grounds are employed in the total spatial perceptions of the normal seeing is as yet undetermined.

The results of this investigation are in agreement with those of Gelb and Goldstein as regards the importance of the visual field for tactual perception.

In general the results are in accord with a *Gestalt* conception of the sensory field which presumes that the field is a functional unit, not an aggregation of discrete modalities. They compel the assumption that the genetically simplest type of consciousness is an organized whole, undifferentiated with respect to quality, and that, qualitatively, there must be a common ground like the visual or the kinaesthetic upon which and partly in terms of which all figures, involving size, position and form, must exist. And finally, they are not in accord with the assumptions of association psychology that the sensory consciousness is composed of parts or elements which blend and fuse *into* a whole. They point to the assumption that the qualitative aspects of sensory consciousness are derived through processes of differentiation that follow organismic rather than mechanistic laws.

X. Conclusions

1. Under all our experimental conditions discrepancies occur between the 'tactual' perception of size and the visual perception of the same size.

2. The discrepancy between 'tactual' and visual perceptions of the same form occur in all individuals, with the different forms and sizes of standards and under all methods and positions employed in the investigation.

A. Within individuals the extent of the discrepancy may amount to a plus or minus 47 per cent of the standard.

B. Within a group the average discrepancy may amount to a plus or minus 12 per cent of the standard.

3. The extent of the discrepancy occurring between 'tactual' and visual perceptions of the same size is greater for the trained subjects than for the untrained.

A. The difference between the two groups is due to the more analytical attitude of the trained subjects who employed more discrete and isolated criteria in forming their judgments, and attempted to construct a whole from its parts.

4. The discrepancy between the two perceptions of the same size was greater when the active method was employed than with the passive.

A. The active method of tactual exploration favors a more analytical perception of form, by emphasizing the discreteness of height and width.

B. The passive method of exploration favors a tactual perception of the form as a whole in which both height and width are included not as discrete aspects but as a proportion.

5. The discrepancy between 'tactual' perceptions of size and visual perceptions of the same size is greater when the 'tactual' perception is made with the object in a vertical position than when it is made in a horizontal position.

A. Vertical 'tactual' perceptions are made with less manual facility and dexterity. The perception is less homogeneous and the criteria for making the judgment are less reliable.

6. Discrepancies between the perception of 'tactual' size and

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visual perception of the same size are greater when the standards are extremely large or extremely small.

A. Objects whose size is convenient for manual exploration lend themselves to more accurate perceptions of 'tactual' size.

7. Although underestimation and overestimation of both height and width do occur, underestimations of both height and width are the usual type of discrepancy.

8. The underestimation of height occurs more often than the underestimation of width.

9. In the act of matching a visual form to a tactual rectangle, a figure more closely approaching a square is usually produced.

10. In the act of matching a visual form to a visual rectangle, a figure more closely approaching a square is produced.

A. The squaring usually takes place in the direction of underestimating the height and either underestimation of width to a less extent or an overestimation of width.

B. Sometimes the squaring is produced by an overestimation of both height and width in the proper proportion.

11. Similar squaring processes occur in both the visual and 'tactual' perceptions of rectangular form. There is a disposition to perceive the figure squarer than it is.

12. The 'tactual' perception of proportion is the most reliable basis upon which to construct a visual equivalent.

A. Greater inaccuracy occurs when less usable criteria are employed.

13. The 'tactual' perception of *size* and *form* is exclusively a visual configuration.

14. No truly tactual patterns were found in the 'tactual' perceptions of form.

15. A. The perceptions of 'tactual' form were carried in visual imagery.

B. Tactual qualities provide 'texture', 'body', and subjective reference but form, extent, position and organization are visual.

16. Apparent movement occurs when the discrepancy between the 'tactual' and visual perceptions is noted. Then the move-

ment seemingly occurs in the line of least action as a process of equilibration whereby one of the perceptions is corrected to the other. This does not, however, eliminate the error.

17. Apparent movement, under these conditions, is a visual adjustment made to two visual extents previously perceived in an erroneous fashion as equal.

18. This apparent movement differs in kind with different observers.

A. Concrete apparent movement occurs in those individuals who perceive movement in their concrete visual imagery. Schematic apparent movement occurs in those individuals who are able to perceive the movement as divorced both from concrete objects and from the body.

19. Apparent movement in its various forms and varieties is always visual under the conditions of our experiment.

20. The exclusively visual nature of apparent movement confirms the fact that 'tactual' patterns do not, as such, exist.

21. The continuity and uniformity of experience, as revealed in this investigation, necessitate the field-concept of sensation, in which one sensory organization serves for all modalities.

22. Throughout our investigation no evidence could be found that a sensory configuration of homogeneous quality (tactual) was organized upon the ground of another and different sensory quality.

23. Visual imagery furnishes continuity between otherwise discrete tactual features of complex 'tactual' perceptions, such as varying intensities and qualities at different places on the skin.

A. Visual imagery furnishes continuity between tactual figure and conscious ground. The ground of 'tactual' perception is visual.

24. The tactual experiences of our observers reveal, without exception, the phenomenon of synaesthesia.

25. Within the limits of our investigation, 'tactual' perceptions are always visual-tactual. It is evident that in the genetic development of these perceptions, in seeing individuals, maturation and specialization take place in visual processes, not in tactual.

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That is, the form, localization, extent, movement, and qualitative differentiation found in so-called 'tactual' perceptions are fundamentally visual.

A. This fact is consistent with the modern trend in psychology to dispense with a systematic differentiation between visual sensation and visual imagery.

26. From the results of this experiment it is necessary to conclude that the tactual field does not function, in seeing individuals, separately from the visual. The two modalities are not, and cannot, be distinct for the purposes of perception. It is an error to speak of a pure tactual or tactual-motor perception.

XI. Appendix of Tables

TABLE I

Overestimations and underestimations—Number of cases out of sixty

	Block 1		Block 2		Block 3		Block 4		Block 5	
	Tr.	Naïve	Tr.	Naïve	Tr.	Naïve	Tr.	Naïve	Tr.	Naïve
Overestimations of Height and Width										
H.P.	14	12	14	12	22	19	23	23	24	22
H.A.	1	20	14	23	19	28	19	27	26	35
V.P.	21	10	28	10	21	10	19	19	14	29
V.A.	6	5	11	9	18	19	16	20	16	25
Total H.	15	32	28	35	41	47	42	50	50	57
Total V.	27	15	39	19	39	29	35	39	30	54
Total P.	35	22	42	22	43	29	42	42	38	51
Total A.	7	25	25	32	37	45	35	47	39	60
Total All	42	47	67	54	80	76	77	89	80	111
Underestimations of Height and Width										
H.P.	42	27	28	27	27	26	27	12	20	24
H.A.	35	25	29	18	36	13	37	10	26	8
V.P.	30	26	25	25	37	22	37	15	38	14
V.A.	36	28	44	29	41	22	48	15	37	10
Total H.	79	52	57	45	63	39	64	22	56	32
Total V.	66	54	69	54	78	44	85	30	75	24
Total P.	72	53	53	52	64	48	64	27	68	38
Total A.	71	53	73	47	78	35	85	25	63	18
Total All	143	106	126	99	141	83	149	52	131	56
Underestimations of Height and Overestimations of Width										
H.P.	5	17	17	19	10	14	10	22	3	13
H.A.	24	15	15	18	5	19	5	22	7	13
V.P.	9	24	4	23	4	26	3	25	1	17
V.A.	19	26	14	21	6	19	8	23	6	18
Total H.	29	32	32	27	15	33	15	44	10	26
Total V.	26	50	16	44	10	45	11	48	7	35
Total P.	14	41	21	42	14	40	13	47	4	30
Total A	43	41	29	39	11	38	11	45	13	31
Total All	57	82	50	61	25	78	26	92	17	61

TABLE I (*Continued*)

	Block 1 Tr.	Block 1 Naïve	Block 2 Tr.	Block 2 Naïve	Block 3 Tr.	Block 3 Naïve	Block 4 Tr.	Block 4 Naïve	Block 5 Tr.	Block 5 Naïve
Overestimations of Height and Underestimations of Width										
H.P.	0	3	0	2	0	1	1	3	2	1
H.A.	0	0	0	1	0	0	0	1	1	4
V.P.	0	0	0	2	0	2	1	1	6	0
V.A.	0	1	0	2	0	0	0	2	5	7
Total H.	0	3	0	3	0	1	1	4	3	5
Total V.	0	1	0	4	0	2	0	3	11	7
Total P.	0	3	0	4	0	3	2	4	8	1
Total A.	0	1	0	3	0	0	0	3	6	11
Total All	0	4	0	7	0	3	2	7	14	12
Totals										
Over H. & W.	42	47	67	54	80	76	77	89	80	111
Under H. & W.	143	106	126	99	141	81	149	52	131	56
U.H.O.W.	57	82	50	61	25	78	26	92	17	61
O.H.U.W.	0	4	0	7	0	3	2	7	14	12
Naïve and Trained Combined										
Over H. & W.	89		121		150		166		191	
Under H. & W.	249		225		222		201		187	
U.H.O.W.	139		111		103		128		78	
O.H.U.W.	4		7		3		9		26	

Total cases 1,200, 60 judgments of each block in each position or method.

TABLE II

Median squaring trained subjects

	Block 1 H	Block 1 W	Block 2 H	Block 2 W	Block 3 H	Block 3 W	Block 4 H	Block 4 W	Block 5 H	Block 5 W
Subject R.K.										
H.P.	77.5	95.6	89.3	103.0	109.0	114.0	120.0	122.0	143.0	130.0
V.P.	100.0	114.0	112.0	129.0	117.0	116.0	132.0	123.0	122.0	100.0
H.A.	97.5	115.0	110.0	126.0	113.0	125.0	137.0	130.0	147.0	130.0
V.A.	100.0	116.0	111.0	131.0	129.0	124.0	136.0	122.0	120.0	102.0
Subject C.W.										
H.P.	99.6	108.0	95.0	102.0	95.9	98.2	94.4	95.0	93.0	100.0
V.P.	82.1	92.5	78.3	90.0	81.7	90.0	76.7	80.0	86.7	90.0
H.A.	90.0	115.0	80.0	93.0	90.8	96.5	88.9	95.0	105.0	108.0
V.A.	91.7	109.0	80.0	95.0	77.5	83.8	77.9	96.7	93.3	98.5
Subject T.P.										
H.P.	82.5	94.4	91.1	107.0	85.0	95.0	91.1	103.0	86.7	95.0
V.P.	79.6	89.0	90.0	100.0	80.8	85.0	80.0	86.7	86.7	92.5
H.A.	80.8	89.4	95.6	104.0	72.4	82.5	97.3	81.7	85.0	103.0
V.A.	75.4	85.0	90.0	100.0	82.5	88.9	82.2	86.7	93.0	100.0
Subject W.W.										
H.P.	72.9	80.6	73.9	85.0	88.2	101.0	105.0	118.0	98.3	120.0
V.P.	99.6	89.4	86.1	96.7	85.8	98.7	91.1	107.0	102.0	110.0
H.A.	61.7	72.5	69.9	82.5	78.3	95.0	87.8	107.0	98.3	122.0
V.A.	62.5	71.9	80.0	86.7	106.0	104.0	120.0	112.0	147.0	140.0

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TABLE II (*Continued*)

	Block 1		Block 2		Block 3		Block 4		Block 5	
	H	W	H	W	H	W	H	W	H	W
					Subject M.R.					
H.P.	77.5	87.5	75.5	83.3	80.0	82.2	73.3	71.7	76.7	65.0
V.P.	91.7	100.0	81.7	84.4	87.5	86.2	88.9	75.0	102.0	70.0
H.A.	91.2	103.0	92.2	107.0	101.0	100.0	104.0	96.7	113.0	97.5
V.A.	103.0	105.0	88.9	95.0	97.5	96.2	97.8	96.7	120.0	80.0
					Subject E.N.					
H.P.	103.0	98.7	112.0	110.0	110.0	111.0	116.0	122.0	137.0	125.0
V.P.	88.5	95.0	106.0	108.0	102.0	102.0	110.0	103.0	113.0	105.0
H.A.	107.0	108.0	120.0	117.0	113.0	117.0	110.0	113.0	123.0	115.0
V.A.	102.0	100.0	119.0	111.0	115.0	105.0	112.0	107.0	137.0	113.0
					Subject K.S.					
H.P.	84.2	87.5	93.9	103.0	98.8	119.0	108.0	132.0	128.0	152.0
V.P.	85.8	88.1	91.1	96.7	91.7	107.0	95.6	108.0	93.3	105.0
H.A.	82.5	90.6	83.3	99.1	98.8	120.0	100.0	120.0	115.0	135.0
V.A.	63.3	73.1	71.7	83.3	72.5	90.1	34.4	100.0	90.0	112.0
					Subject R.W.					
H.P.	83.3	95.0	90.0	100.0	83.3	96.2	82.2	98.3	80.0	90.0
V.P.	103.0	95.0	103.0	117.0	85.9	97.5	85.7	96.7	90.0	87.5
H.A.	57.9	70.0	52.2	68.3	50.0	67.5	51.1	70.0	55.0	80.0
V.A.	70.0	85.0	55.9	73.3	48.3	67.5	70.7	110.0	55.0	82.5
					Subject D.P.					
H.P.	77.5	85.0	83.9	95.0	89.1	95.0	88.9	91.6	102.0	100.0
V.P.	56.3	78.7	57.2	79.2	56.7	75.5	51.1	71.7	61.7	85.0
H.A.	75.8	83.6	75.0	85.0	70.0	72.5	67.8	75.0	80.0	80.0
V.A.	67.2	75.0	73.9	79.2	77.5	70.0	83.3	67.3	88.3	65.0
					Subject H.B.					
H.P.	113.0	129.0	128.0	147.0	143.0	160.0	140.0	158.0	133.0	157.0
V.P.	117.0	139.0	117.0	141.0	136.0	159.0	133.0	155.0	147.0	190.0
H.A.	94.2	101.0	104.0	114.0	124.0	134.0	117.0	127.0	138.0	140.0
V.A.	90.8	96.2	90.0	104.0	95.9	115.0	100.0	120.0	115.0	130.0

TABLE III

Overestimations and underestimations; trained relative to naïve; per cents

	Block 1		Block 2		Block 3		Block 4		Block 5	
	H	W	H	W	H	W	H	W	H	W
					All Subjects, Positions and Blocks					
H.P.Tr.	—13.7	—3.7	—6.7	4.0	—1.8	7.0	2.0	11.0	7.8	13.4
N.	—5.0	1.0	—7.0	1.0	—5.0	5.0	—5.0	10.0	0.0	15.0
V.P.Tr.	—9.5	—1.9	—7.8	4.0	—7.3	2.0	—6.5	.7	.5	13.6
N.	—10.0	3.0	—12.0	3.0	—9.0	5.0	—5.0	10.0	0.0	10.0
H.A.Tr.	—16.0	—5.1	—10.8	—.4	—8.9	1.0	—3.9	1.6	5.9	11.1
N.	—7.0	3.0	—5.0	8.0	—1.0	17.0	4.0	20.0	10.0	20.0
V.A.Tr.	—17.5	—9.4	—13.9	—4.1	—9.7	—5.5	—3.6	1.9	5.8	2.4
N.	—17.0	2.0	—16.0	1.0	—7.0	12.0	—5.0	16.0	3.0	15.0
Av.Tr.	—14.2	—5.0	—9.8	.9	—6.9	1.1	—3.0	3.8	5.0	10.1
Diff.Tr.	9.2		8.9		8.0		6.8		5.1	

TABLE III (*Continued*)

	Block 1		Block 2		Block 3		Block 4		Block 5	
	H	W	H	W	H	W	H	W	H	W
Passive Method										
Trained	—11.6	—2.8	—7.3	4.0	—5.0	4.0	—2.2	5.9	4.1	13.5
Diff.	8.8		11.3		9.0		8.1		9.4	
Naïve	—7.5	2.0	—9.5	2.0	—7.0	5.0	—5.0	10.0	0.0	12.5
Diff.	9.5		11.5		12.0		15.0		12.5	
Active Method										
Trained	—16.7	—7.2	—12.4	—2.2	—9.3	—2.3	—3.7	1.8	5.8	6.8
Diff.	9.5		10.2		7.0		5.5		1.0	
Naïve	—12.0	2.5	—10.5	4.5	—4.0	14.5	—5.0	19.0	6.5	18.0
Diff.	14.5		14.5		19.5		18.5		11.5	
Horizontal Position										
Trained	—14.8	—4.4	—8.7	1.8	—5.3	4.0	—.9	6.3	6.8	11.8
Diff.	10.4		10.5		9.3		7.2		5.0	
Naïve	—6.0	2.0	—6.0	4.5	—3.0	11.0	—.5	15.0	5.0	17.0
Diff.	8.0		10.5		14.0		15.5		12.0	
Vertical Position										
Trained	—13.5	—5.7	—10.8	—.05	—9.0	—1.7	—5.0	1.3	3.1	8.0
Diff.	7.8		10.3		7.3		6.3		5.0	
Naïve	—13.0	2.5	—14.0	2.0	—8.0	9.0	—5.0	13.0	1.5	12.5
Diff.	15.5		16.0		17.0		18.0		11.0	
All Positions and Methods Combined										
Trained	—14.4	—5.0	—9.8	.9	—6.9	1.1	—3.0	4.0	5.0	10.1
Diff.	9.4		10.7		8.0		7.0		5.1	
Naïve	—9.7	2.2	—10.0	3.2	—5.5	9.7	—2.7	14.0	3.2	15.0
Diff.	11.9		13.2		15.2		16.7		11.8	
All Subjects Combined										
Tr. & N.	—12.1	—1.6	—9.9	1.1	—6.2	5.4	—2.4	8.9	4.1	12.5
Diff.	10.5		11.0		11.6		11.3		8.4	

(For example, —13.7, the first figure in column one, means that trained subjects underestimate height in the horizontal passive method 13.7 per cent. The first figure in column two means that trained subjects underestimate width of Block No. 1 3.7 per cent in the horizontal passive method.)

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A TACHISTOSCOPIC STUDY OF THE DIFFERENTIATION OF PERCEPTION

by

ROBERT L. BRIGDEN

The purpose of this experiment was to make a qualitative tachistoscopic study of visual perception, giving particular note to the changes observed in a simple ink drawing as it is differentiated from a homogeneous field, and to relate the results of this experiment to the conclusions of investigators in other fields of behavior.

I. HISTORY

In spite of the heterogeneity of apparatus, technique and assumptions of experimenters in perception, the results of their researches have been remarkably uniform. Erdmann and Dodge (4) found that words of 22 letters could be perceived more accurately than 7 letters which did not form a word, and that if the three parts of the letter *K* were presented separately, reproduction was difficult and inaccurate, while if the *K* itself were presented, observers had no difficulty in reproducing it. Dickinson (3) divided perceptual differentiation into three periods: *visual pattern* ("a thereness, clear in contour but lacking in logical meaning"), *generic object* (parts begin to stand out in sharp relief), and *specific object* (forms take on stability; they have specific characteristics). Smith (9), on the other hand, believes that there are two stages in the process of perception. They are (a) "an immediate interpretation of the object as a whole, and (b) an analysis of this vaguely apprehended whole into its component parts". In a recent study Snygg (10) lists the changes observed in reproductions of tachistoscopically presented figures. They are (1) increased stability of pattern, (2) equalization of distances, (3) increased symmetry, (4) tend-

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ency toward closure, and (5) differentiation of a relatively homogeneous field. In an experiment on memory, Perkins (7) obtained similar changes in his observers' reproductions from memory. Briefly then, these studies have indicated that changes in perception have occurred as a detailed stable pattern was differentiating from an originally homogeneous field.

II. Apparatus and Method

The apparatus for this experiment included a tachistoscope modeled after Dockeray, with a camera shutter, and a timing device for regulating exposures of 1 second or longer. A non-frosted 25-watt bulb furnished 1.8 foot candles of light. For exposures of less than one second, the camera shutter admitted the light to the tachistoscope. For longer exposures a device was used which consisted of a kymograph drum, rotated on its axis by a constant speed-motor, and a relay which was actuated, for given intervals, by the kymograph. The surface of the drum was covered by a non-conducting paper from which strips had been cut, exposing the drum in lengths corresponding to the desired exposure time. Thus as the drum was rotated, a flexible pointer made contact over a known length of the circumference, actuating the relay, and thereby closing the main circuit and lighting the bulb in the tachistoscope. (See Fig. 1, A.)

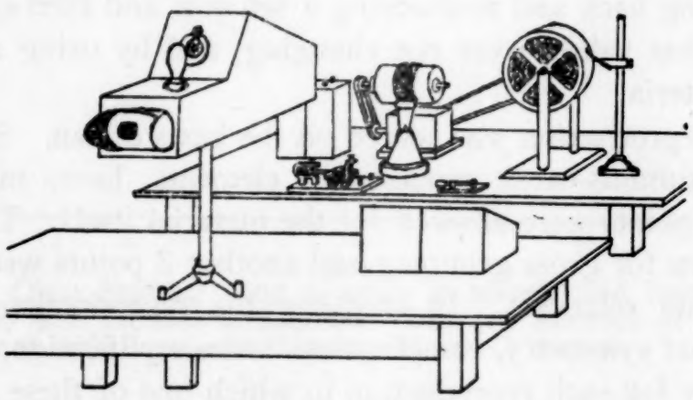
There were four parts to the experiment. In Part I a series of 20 stimulus cards, 4 inches by 5½ inches, bearing simple geometric figures within a 2-inch by 3-inch area were shown to 60 observers at 1 of 5 different exposure times: 6 sigma, 10 sigma, 20 sigma, 40 sigma or 200 sigma.

The observer was seated before the tachistoscope and the following instructions given him: "I am going to show you a number of slides with various simple drawings on them. You are to look into the tachistoscope before you and see as much of each slide as possible. When the light goes off, each time, you are to reproduce what you saw as accurately as you can. In case you do not see *what* something is, but do see *where* it is, represent it with an *X*. Your score for each picture will depend on the accuracy of your production of it. I will say 'Ready', 'Now'

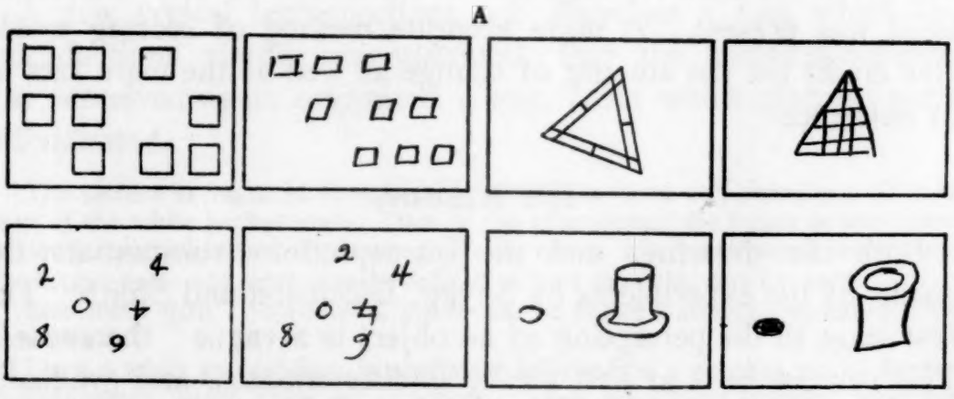
and will then expose the slide for a very brief time. When I say 'Ready', hold yourself tense and direct all of your energy toward the eyepiece so as to see as much as you can. Are there any questions? . . . All right. . . . 'Ready' . . . etc."

One second was allowed to elapse between the "Ready" and "Now" and the time the shutter was clicked. The observer was given as much time as he desired to make his drawing. The subjects were asked, after the third and again after the last exposure in the series, to describe verbally any changes which he had perceived in the figures.

The purpose of Part II was to test further the results of Part I in order to learn whether the changes observed were due to the peculiarities of the stimulus-cards or to some general principle. Similar technique and similar stimulus-cards were employed. There were 16 observers.



A



B

FIG. 1. A. Apparatus to Test Differentiation of Perception. B. Sample Stimulus Cards and Sample Reproductions of Each Card (stimulus card is followed by reproduction in each case).

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The results of Part I clearly indicated that an exposure time greater than one-fifth of a second would be necessary in order to obtain a complete record of perceptual evolution. Part III traced this evolution from 6 sigma to 4 seconds in 21 subjects. A new set of 32 cards was prepared and four of them (one containing 6 numbers, one having 6 letters and two bearing simple line drawings) were exposed 6 sigma, four at 40 sigma, another four at 200 sigma and so on at ½, 1, 2, 3, and 4 seconds.

In the fourth part of the experiment, 21 subjects were permitted to observe the stimulus-cards used in Part III, as long as was necessary "to make a perfect reproduction." After each exposure the observer made his reproduction.

An unavoidable fault of the scoring was its subjectivity. An attempt was made to make it as objective and uniform as possible by scoring all of the reproductions at once, grading them all at once, going back and re-checking a set now and then in order to be sure that values were not changing, and by using a constant set of criteria.

Each reproduction was scored on the basis of ten. Since most of the stimulus-cards contained 6 elements, lines, numbers or letters, 6 points were allowed for the material itself. Two points were given for gross grouping and another 2 points were allowed for minute relations. In studying the reproductions for the presence of symmetry, complication, and simplification, one point was given for each reproduction in which one of these characteristics was present. A more accurate method of scoring would give credit for the amount of change as well as the mere fact of its existence.

III. Results

Both the drawings and the introspections substantiate the results of the experiments by Snygg, Dickinson and Smith. The first stage in the perception of an object is a vague "thereness". This perception is at first totally undifferentiated, and gradually develops until the general outline or pattern is discernible. Reproductions of plates seen at 1/150th of a second show great simplification of minute detail and complication of gross structure. In

Part I the best gross reproductions were obtained at 1/100th of a second. A period follows which yields much poorer drawings. In Part III of the experiment it was seen that this period of inaccuracy ends between 1/5th of a second and 2 seconds, and from that time the accuracy curve ascends. (See Fig. 2.)

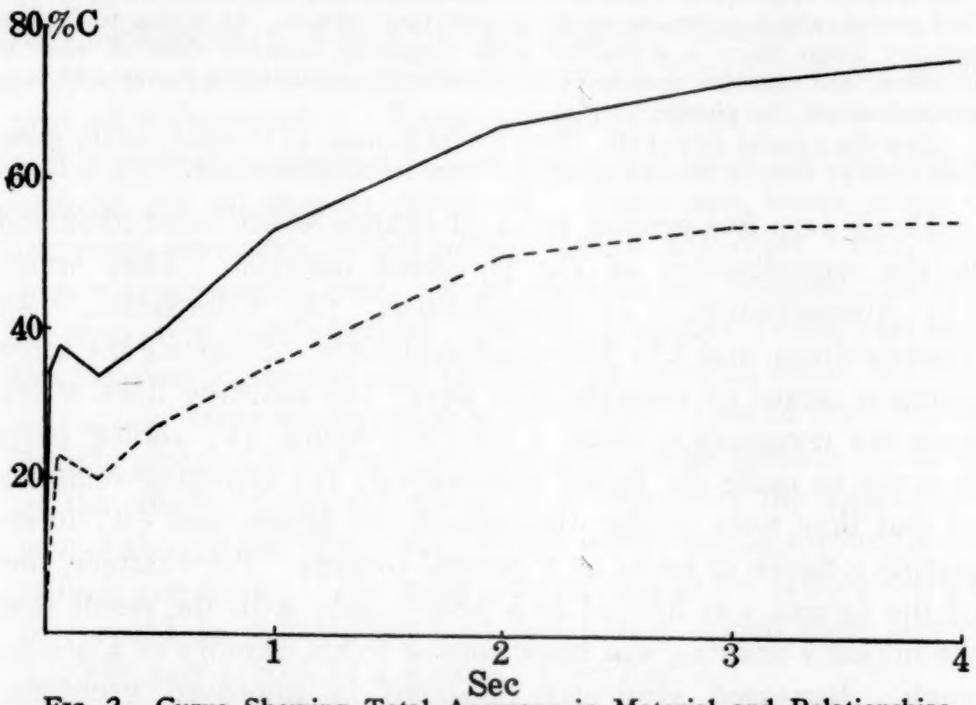

FIG. 2. Curve Showing Total Accuracy in Material and Relationships (solid line) with Increase in Exposure Time, and Accuracy of Material (dashed line) with Increase in Exposure Time. C, correct.

A few typical introspections will illustrate a fact which the reproductions vividly demonstrated: that the stimulus-material was perceived as an organized whole, from which discrete parts individuated.

"The picture is vague at first, then definite lines stand out, seeming a little in front of the white background. Then in the after-image the figure is very clear for an instant and then disappears. Form comes after a general impression. The larger parts are more clearly defined at first than the smaller parts."

"Saw more than I reproduced, but it was so vague I couldn't verbalize it or reproduce it."

"I saw a white ground first, immediately followed by a popping out of figures simultaneously, which came out in groups. Then individuals emerged from the group. Position comes before identity of number. I am sure that I grouped the material more symmetrically than it was in the stimulus card, but don't know how. I immediately organized the material into patterns. Memory becomes exclusively patterned. Saw big things first, small later."

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"See general pattern followed by individual particulars."

"Saw figures largely in the after-image."

"Saw squares shift transversely to form stable and familiar patterns. Things become very symmetrical in the after-image. There is always something about every figure that stands out."

"See first the group of black outlines always as a group, then follows the process of differentiation, in which the parts are perceived in relation to the first unitary impression. There is a rapid expanding movement of the white background which grows to maximum and then recedes. In trying to form a memory image there is a conflict quite frequently between ideas of what is perceived and elements that were never actually perceived apparently forcing themselves into the picture."

"Saw the general form first. Then I tried to make an inventory of the parts. Saw some of them in the real image and some in the after-image."

There were five general types of change which were identified in the reproductions of the perceived material. They were: (1) Simplification, (2) Complication, (3) Completion, (4) Transposition, and (5) Increased symmetry. Some of the more common means of simplification were: (a) omitting lines which were not necessary to make a complete figure, (b) adding parts in order to make the figure symmetrical, (c) changing relations so that they were similar throughout the figure, and (d) interpreting a figure in terms of a general concept. For example, one of the figures was likened to a honeycomb, with the result that the subject's drawing was made similar to his memory of a honeycomb. Increased symmetry appeared in improved grouping, bilateral symmetry and altered relations between parts of a figure.

There were a great many more cases of complication at 1/150th of a second than at any other exposure time. Thirty-seven per cent of the reproductions of figures seen at 1/150th of a second showed complication, while the next highest percentage was 18.5 per cent at 1/25th of a second. The amount of complication per figure was likewise greater at 1/150th of a second than at any other time.

Part III yielded confirmation of a phenomenon which had appeared in Part I. Both parts of the experiment indicated that the genesis of perception is not a smooth continuum when measured in terms of accuracy.

In both Part I and Part III, it was found that there were three trends in the curve picturing the accuracy of reproduction of the visually perceived figures. The first trend, apparent up to and

including 1/100th of a second, was followed by a second and *downward* trend, which terminated between 1/5th of a second and 2 seconds. In this second phase the accuracy of the reproductions often fell below what it had been at the briefest exposure time, 1/150th of a second. The third phase was characterized by a gradual improvement in accuracy. Let us consider in detail the characteristics of each of these phases of perception.

The most outstanding characteristic of Period I is the grossness of differentiation. Large groupings, large objects, outlines and a general impression of size and a still more general idea of content are all that is perceived. There are fewer cases of increased symmetry in this period than in any other. *But, what is seen is accurately seen.* Gross relations are, however, the limit of perception in this period. Squares, triangles, circles and similar familiar forms are also identified as to gross form, but their content, or inner organization is never seen. One of the stimulus-figures pictured a triangle containing a simple pattern. Not one of the observers was able correctly to reproduce the internal pattern, although the figure was always recognized as a triangle containing *something*. The most general and gross factors were all that could be differentiated in this period which ends between 1/100th and 1/50th of a second. (See Fig. 2.)

The second period is characterized by a less accurate gross differentiation, and the appearance of the finer patterning, inaccurately perceived or remembered. Both the gross relations and the finer interrelations are distorted. The length of this second period is 1/20th of a second or less.

The third period begins at the end of the second period and, under the conditions of this experiment, continued from 4 to 13 seconds, with the average of 6.6 seconds. At the end of this third phase of the genesis curve the most accurate perception, under the conditions, is found. Throughout the period both the arrangement and the accuracy of reproduction of material improve together.

The introspections and drawings of the subjects yielded a number of other interesting facts. Approximately 5 per cent of the drawings were changed toward greater symmetry after

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apparent completion. The observer would make his reproduction and then as he looked at it, would decide that it was too asymmetrical and he would change it toward greater symmetry.

Verbalization seemed to play a large part in determining the accuracy of the reproductions. Two observers indicated that no matter how brief the exposure time, if they could see the material long enough to "put it into words" they could reproduce it. Sometimes they would see the material but it would fade before they could differentiate it to the extent of verbalization.

Stimulus figures which, according to introspective reports, were easy to perceive, were simplified in the reproductions. Plates which appeared complex were reproduced with much complication. This was particularly evident in the case of crossed lines, whose pattern was not definite. If in the stimulus card three lines were crossed, the average observer would indicate four lines in his reproduction.

At least a dozen observers mentioned the fact that they forgot the material before they could reproduce it in a drawing.

Eighty-seven per cent of the reproductions of figures seen at one-half second showed that one factor or feature was emphasized at the expense of others. Ninety-seven per cent of the reproductions of figures seen at 1/150th of a second exhibit the same phenomenon.

IV. Discussion and Conclusions

One of the first facts demonstrated by this experiment was that perception is the differentiation of a homogeneous field in such a way that the parts emerge *already* unified and patterned. Both the introspective material and the reproductions substantiate this. Not one of the 2,768 reproductions made by the observers was lacking in some sort of organization. The pattern was perceived before its content was identified. "I saw a white ground first, immediately followed by popping out of figures simultaneously." "See first the group of black outlines always as a group." "Saw the general form first. Then tried to make a mental inventory of the parts." "My first impression is of a white field against which various figures rest."

Both the drawings and the introspections are very definite evidence that this patterning is not a conscious adding or organizing or synthesizing of parts. It occurs before, or as, the parts are identified. One observer, whose vision was deficient, was never able to analyze the stimulus-figures to the extent of recognizing the parts. His reproductions are merely wavy lines or circles or triangles corresponding to *where* the figures were, not to *what* they were. The same was true, but usually less obvious, in all the reproductions where differentiation was slight. From these facts we conclude that the field is perceived as a whole, and that the relative location of the parts of the figure is differentiated first.

These observations substantiate the results both of Dickinson, who divided perception into the three levels of Visual Pattern, Generic Object, and Specific Object, and of Smith, who divided perception into two stages, (1) the immediate interpretation of the object as a whole and (2) an analysis of the whole into its component parts.

The most striking result of this experiment is the identification of the three phases in the accuracy curve of perception. This discovery immediately raises the question: Is the second phase in the curve characterized by a decline in accuracy, the result of some artifact, or is it genuine? Causes of error might be, (1) that the material perceived during the supposed decline was more difficult than that seen during the other two periods, (2) the scoring, (3) a period of fatigue or loss of interest in Part III, or (4) a poorer group of observers in Part I.

All of these possibilities are checked by the methods of the experiment. Even if the material perceived in Period II had been more difficult in Part III, still the characteristic drop is noted in Part I where the same material was used at each exposure time, with a different group of subjects. Thus with the same material, the drop in accuracy occurred. The phenomenon cannot be attributed to the variability of the material. The same method of scoring was used for each exposure time, so that while absolute values might be open to criticism, the relative values are constant throughout. Great care was taken that this be true. The drop

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could not, therefore, be the result of the scoring. Another possible criticism would be that the subjects lost interest or became fatigued, causing a temporary decline in the accuracy curve. There was no outward sign of fatigue and the subjects reported no loss of interest in the experiment. It is probable, moreover, that even had some of the observers become disinterested, their depression or fatigue would have appeared at more widely different times. There was nothing in the procedure to make the observers regain interest toward the last, in Period III. It rarely required more than 10 minutes for an observer to see all the cards and make the reproductions, and in such a brief period as this fatigue could hardly have been an important factor. Fatigue will in no way explain the uniformly poorer reproductions made at 1/5th second in Part I of the experiment where the reproductions of a whole group of observers showed a decrease in accuracy. The last suggested criticism is that a poorer group of observers acted as subjects in Part I where the exposure time was 1/5th second. To prevent anything of this nature, more than 3 or 4 subjects never observed consecutively at the same exposure time. Three or four would observe at 1/150th of a second, then the same number would observe at 1/100th of a second and so on. With such a technique it is very improbable that more than an average of poor observers would be placed in any time group. Also the *type* of observers would not explain the results in Part III where one observer went through all of the exposure times. Thus Part I and Part III acted as mutual checks. We feel, therefore, that since the above chances for error were checked in one way or another, that the results are significant.

The next problem is to explain the fact that the growth of perception is not a constant upward curve in terms of accuracy. Our data indicate that the decreased accuracy of perception between 1/100th of a second and 1 second is caused by perceptual changes and a resulting unstable condition of the observer's memory image of the perceived material. To illustrate this we will follow through the perceptual process making only such statements as can be substantiated with either the reproductions made by the observers, or by their introspections.

Under the conditions of this experiment the observation begins with darkness. When the light is turned on, illuminating the inside of the apparatus and the stimulus-card, the first thing that is perceived is gamma movement. Out of this general brightness indefinite shadings are differentiated. They become increasingly certain until they are recognized as rather definite forms. What changes have taken place thus far have not served as distractions, but after this point, at which the best gross organization is perceived, the perceptual expansion, and expansion of size of the field, present a larger, more complicated, perception *which the observer immediately starts to analyze.* Objects not noted before are now seen. The size of the card, the frame of black wood in front of the stimulus-card, the blackness of the interior of the tachistoscope, the nature of the card on which the stimulus-figure is drawn, ink spots on the paper, and a number of similar things show that the size of the field and the perception itself have undergone expansion and differentiation. There is a limit to which this can go, and the end of Period II probably marks the limit. Although we had no means of verifying the presence of eye-movements, it is possible that they began during this period. Koffka (6) gives 1/50th of a second as the probable time when eye-movements would begin. Whatever be the mechanism, the analysis of the field continues until the maximum differentiation, under the conditions, occurs.

With exposures of 1/150th of a second or 1/100th of a second the perceptual field was limited and undifferentiated. The resulting reproductions were likewise limited and crude. The 1/5th or 1/2 second exposures provided ample time for eye-movements, for analysis, and for changes of fixation. The introspective reports and the drawings indicate their presence. Thus we have two different conditions: the first phase of perception, limited in size and differentiation and very stable; the second phase, transitional, analytical, expanding and therefore unstable. This second period is a critical phase of perception. Analysis has destroyed the whole, and part differentiation is very rudimentary. The sudden inaccuracy of perception at this point leaves the observer with only a confused idea of what he has seen. He is

unable properly to relate the parts to the whole perception and the parts have not been differentiated sufficiently to become stable, themselves. Summarizing, we may say that the decline of accuracy in Period II is caused by the interruption of perception at a critical point, where analysis has divided the pattern into unstable parts.

One of the purposes of this experiment was to relate its results to those of experiments in other fields. More than 90 per cent of the reproductions were more symmetrical than the stimulus-material. The stimulus-sketches were purposely arranged asymmetrically and all of the changes in the reproductions indicated improved arrangement. Experimenters both in the field of perception and in other fields have noted this increased symmetry. Snygg, Wiegand, Dickinson and Smith report its presence in their experiments on perception and Wulf, Gibson and Perkins record the same changes in their experiments on memory. The above investigations as well as the present one also disclosed equalization of distances between perceived objects, closure, simplification, complication, completion, verbalization, and balancing of parts.

The apparent similarity between perception and memory seems to confirm the configurational theory that all behavior follows the same principles. This theory is further substantiated by the fact that all types of behavior overlap. An experiment in memory cannot be conducted without the use of perception. Likewise an experiment in perception cannot be conducted as this one was without the use of memory. But is not the same true of other behavior? An experiment in learning involves perception and memory. An analysis of any of the sensory processes will also involve perception and memory. Thus the results of this experiment and those cited above substantiate the hypothesis that all behavior follows the same principles both because of the similarities between memory and perception and the fact that perception and memory form some part of any behavior pattern.

V. Summary

1. Under the conditions of this experiment, perception involves the differentiation of a homogeneous field in such a way that the parts emerge already unified and patterned.

2. There are three characteristic phases in the differentiation continuum as indicated by the observer's reproductions:

a. Period of gross differentiation ending at approximately 1/100th of a second.

b. Period of less accurate and stable perception, terminating between 1/5th of a second and 2 seconds.

c. Period of highest differentiation, reaching its maximum between 4 and 13 seconds, for the material employed in this experiment.

3. The relative location or grouping of the stimulus-figures is perceived before the material itself is identified.

4. The following types of change were identified in the reproductions of perceived material: (1) Simplification, (2) Complication, (3) Completion, (4) Transposition, and (5) Increased symmetry by means of: Altered relations between parts, bilateral symmetry, and improved grouping.

5. All of the changes mentioned under 4 above occur also in memory reproductions.

6. Ninety-two per cent of the observers emphasized one or more parts of their reproductions at the expense of other parts.

7. The results of this experiment are harmonious with the hypothesis that all behavior follows the same principles.

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A QUALITATIVE ANALYSIS OF THE LEARNING OF HUMAN SUBJECTS ON VARIABLE PATTERN MAZES[1]

by

DONALD F. SHOWALTER

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I. INTRODUCTION

The great diversity of theories and even of interpretations of experimental data in the field of learning indicates that the fundamental basis of learning has not been distinguished from its superficial aspects. Underneath all the apparently conflicting evidence there must be a unifying principle. To secure an analysis that may help to disclose the fundamental basis of learning is the purpose of the experiment herein described.

To avoid misleading, superficial phenomena, three principles of procedure were determined upon. In the first place, to prevent the coarseness of the measurements hiding significant facts, the thirtieth of a second was chosen as the unit of measurement. Second, to prevent the characteristics of individual learning being

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covered up in averages, the study was made qualitative rather than purely statistical. Finally, since it was felt that the perception of form may be an important factor in learning, conditions presumably influencing the perception of form were systematically varied to determine their part in the learning process.

II. The Experiment

The material was a T-type maze. Two forms and five patterns were used. The first form was a mimeographed sheet containing twenty-one columns of figures in twenty-one rows double spaced between the rows and the columns. These figures were so arranged that by starting at the 0 at the top and connecting in order the numbers from 0 to 60 one and only one path could be

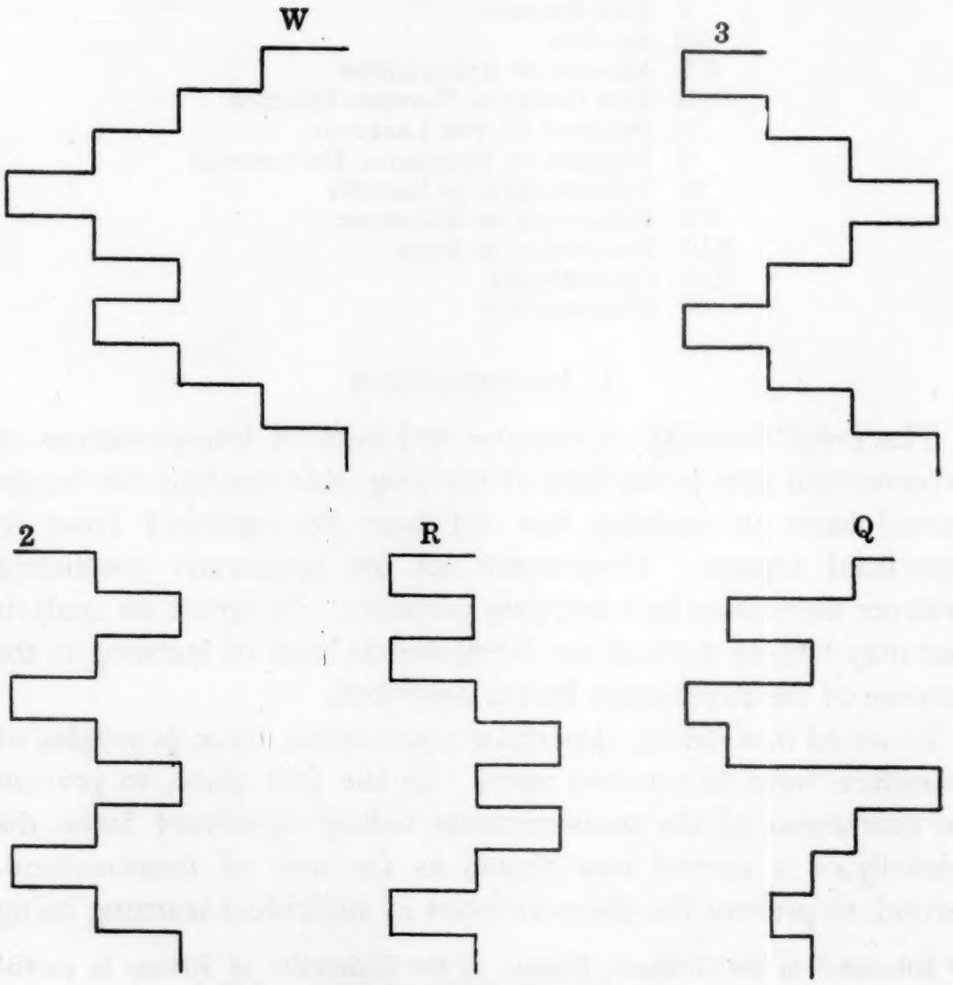

Fig. 1. Maze Patterns.

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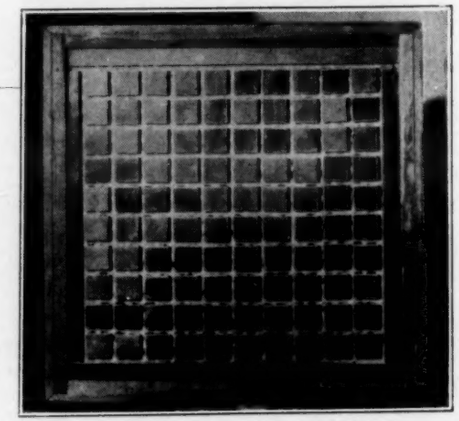

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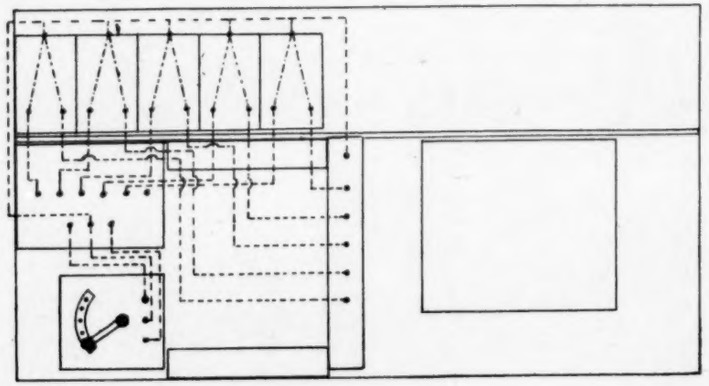

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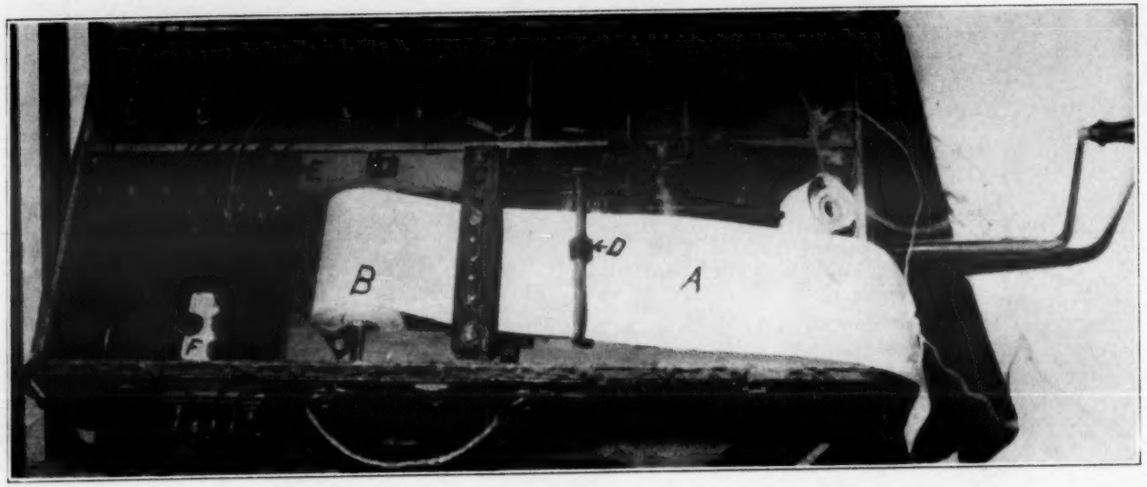

W

FIG. 2. X. Top View of Metal Maze.
Y. Wiring Diagram for Recording Apparatus.
W. Complete Recording Apparatus.

drawn on the sheet. Four patterns were used, each of which consisted of ten equal units composed of a horizontal line of five numbers followed by a downward line of three numbers. At the end of each unit there was a cul-de-sac equal in size to the next unit but extending in the opposite direction. The patterns as indicated in Fig. 1 differed only in the number and order of the changes in direction of the horizontal lines. Patterns W, R, 3 and 2 were used.

The second form, shown in Fig. 2, was a recording maze so arranged that the stylus which ran in a groove touched a contact every half inch, making an accurate record of the path taken. The board was cut into one hundred twenty one-inch squares by an equal number of horizontal and vertical grooves. The subject was able to trace the correct path through the maze because he was warned by a buzzer when he made an error. There was no way for him to tell before he made the move whether or not it was correct unless he had figured out the pattern in advance or remembered what he did on the previous trial, except that a few, who had especially keen sensitivity for tone differences, could tell a difference in the recording coils. In this case the subject had to detect a plan by auditory rather than visual cues but he still had the task of perceiving a plan. The advantage of this form was that the recording was entirely automatic, which not only insured accuracy but left the experimenter free to record observations. The lower ends of the contacts in the maze could easily be threaded in any arrangement so that it was a simple matter to change from one maze to another.

The recording apparatus consisted of a set of five Ford coils connected to the ground of a transformer, and a phonograph motor arranged to pull a piece of adding machine tape between five pairs of points. The maze-form and stylus were connected so as to complete circuits through the primaries of the coils and thus send the secondary currents across the points to mark the paper at appropriate times. Each coil worked independently of the others so that five separate records could be made. The motor carried the paper at a uniform rate of thirty millimeters per second so that the time in thirtieths of a second could be read

directly by measuring the distances between spark burns in millimeters. The complete apparatus and the wiring diagram are shown in Fig. 2.

III. Subjects

Sixty-three subjects worked with the paper maze and ten with the recording maze. The latter were sophomores, juniors, seniors, and graduate students, who had each had some course in psychology. The former were all sophomores except ten and were all taking their first work in psychology. The subjects ranged in age from eighteen to thirty-five but only five were over twenty-five. In referring to the subjects individually, key numbers are used: the first part of the number indicating the pattern and the second part the method used in learning.

IV. Procedure

Subjects worked during a regular fifty-minute class period, most of them coming twice. All work was done in a small experimental room bare of furnishings other than the necessary apparatus, and care was taken to avoid any remarks or actions which might suggest that the mazes were organized. That the procedure might be uniform, each subject was given a typewritten set of instructions as soon as he entered the room. These instructions gave detailed directions for completing the task and included a copy of a small section of the maze with the numbers connected in the proper manner and with the errors pointed out that subjects in preliminary tests had made. The directions stated that the subject's record would not be counted for or against him but on the other hand urged that he do his best.

Time was recorded on the recording apparatus at the moment the paper maze was uncovered and at the end of each of the ten units. With the recording maze the starting time and the time of completion of each of the one-inch lines, as well as the beginning and end of each error, was recorded. This made it possible to read the time spent on each unit, on each section of each unit, and on each error. In addition, the number of errors, their location, and direction could also be read.

On the paper maze eight methods were used, twelve subjects working on each of the first four methods and three on each of the others. The purpose of the different methods was to vary the factors that might have an influence on the perception of form. In Group A the subject traced the path with a round pointed glass rod which left only a faint mark. After making one run without error or appreciable hesitation, he was asked to draw the path on a paper where the numbers had been replaced by dots. If the first drawing was not correct, he made another run of the maze and a second drawing on the dots. This was kept up until a correct drawing was made. In Group B the subjects worked as in Group A except that a drawing was made after every trial on the maze. Groups C and D worked as did Groups A and B, respectively, except that the maze was traced with a pencil in place of the glass rod. The members of Group E worked like those in Group D except that to their instructions was added the following, "The path which you will draw makes a fairly simple pattern. Watch for this pattern as you draw." The members of Group F also worked as did those of Group D except that at the end of the first trial they were given thirty seconds and told to look the path over, as they would be asked to draw it. The instructions were not repeated but the thirty seconds was allowed at the end of each trial although few of the subjects used all of it. The members of Group G traced the maze with a glass rod on a sheet of transparent celluloid on which it left no mark. The record of the path followed by the subject was kept with a carbon paper under the maze. This group also made their drawings with the glass rod on the celluloid so that at the end of learning the patterns, a subject had not yet seen any pattern that he had drawn or traced. Each subject in Group H worked blindfolded and had his pencil guided through the maze by the experimenter. The drawing was made with the blindfold removed.

The order in which the four patterns, 2, 3, R, and W were used, was rotated to allow for possible differences in the difficulty of the different patterns. The drawings were introduced in order to secure objective evidence of what each subject actually knew

about the pattern at different stages of the learning process. The introduction of the instructions to make a drawing of necessity changed the goal in the mind of the subject. To allow for this the drawings were in some cases introduced at the beginning of the experiment and in others at the completion of learning to trace the path.

V. The Records

For each subject there are four records:

(1) The total time for each trial and the time used on each of the ten units of the trial. On the recording maze there is, in addition, the time used in each section of a unit and in each error. All time records are in thirtieths of a second.

(2) The number and length of all errors on the paper maze and the number and direction of all errors on the recording maze.

(3) An indication of the subject's knowledge of the form of the path at every stage in the learning process as indicated by his drawings which, being on paper marked in units, could be scored objectively as to direction, size, and number of units.

(4) Introspections taken at the end of the learning. These were supplemented by records of the remarks made by the subjects as they worked and by observations made by the experimenter about the behavior of the subject. All remarks and observations were recorded at the time they were made.

VI. Results

Individual differences were much more striking than uniformities, and were apparent in every feature of the records—in the efficiency of the learning, the shape of the learning curve, the time used on the first trial, the time for learning one pattern, the decrease in time between the first and fourth patterns, the number of trials on the first pattern, the reduction in number of trials between the first and fourth pattern, the number of errors, the time used on errors, the kind of errors, and the persistence of errors. The longest time used in learning the first pattern by a subject who mastered it is nearly eight times as great as the shortest time. Subject 2C2 used almost as much time on the

fourth as on the first pattern, while subject RA1 used twenty-four times as much time on the first as on the fourth. Our problem is: How may we account for these great individual differences? Heron (3) thinks that chance and individual ability play important rôles with chance often in the lead. Husband (4) and Warden (11) emphasize the type of imagery employed in the attack upon the problem. The latter also proposes the various laws of association to account for learning. An analysis of the data that follow shows that factors commonly used to explain learning do not account for the differences in individual performance but that certain other factors actually do show important influences upon the learning process under the conditions of the present experiment.

VII. Results of Stimulation

That learning took place is evident. That it took place at various rates and in diverse forms in the different individuals has also been shown. The real problems are: What starts the learning, and What causes it to progress? It is self-evident and generally admitted that stimulation is essential not only to learning but to any response. What is equally important, although not so often recognized, is that stimulation is always stimulation toward something, that is, in some particular direction, and that in an organized system the reaction must follow a definite path or pattern. Even in an inorganic set-up any change in the conditions initiates a change which is in a definite direction and goes on in a definite way. Thus in a super-saturated salt solution, continued drying, or the introduction of a salt crystal, precipitates a change which is in a definite direction, that is, toward a definite goal, the crystallization of the excess salt, and which proceeds by a definite plan that can be predicted in advance. Likewise, in the human being, a simple stimulation such as a pin prick or a burn very definitely stimulates the individual in a definite direction or toward a particular goal. In such a circumstance there is one and only one direction of response and that is away from the noxious stimulus. When there is a more complex stimulating situation, the goal is equally sure to be present

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although sometimes it is not easy to verbalize. This latter fact has led to the assumption that a goal is not necessarily present, but inability to verbalize the goal toward which a stimulus points is not evidence against its existence or even its definiteness. The fact that a savage cannot verbalize the law of gravity does not prevent that law from acting upon him in a very precise fashion.

What goal is set up depends on a variety of factors but the goal is invariably there. In the present problem the goal was set up by the reading of the directions. The directions were uniform for all individuals in the same group, but the individuals differed. The resulting goals also differed. In some cases a goal of speed was set up while in others a goal of errorless procedure was set up. For those subjects who did not make a drawing until a correct run had been completed the goal at first was, as a rule, a correct run, but later it became a correct drawing. Thus subject RR1 learned to make a correct run in sixteen trials but required twenty more before making a correct drawing, and subject RA3 made a correct run in four trials but did not make a correct drawing in his fourteen subsequent trials. On the other hand, subjects who made the drawing after every trial had the goal of correct drawing from the beginning and not infrequently made a correct drawing before making a correct run. It is thus evident that the one task is not harder than the other but that the goal set up determines what is learned.

The correct apprehension of the significance of goals clears up in many ways the problem of incidental learning. For example, in the present experiment, a subject was often able to make a correct drawing when first asked to do so not because he had learned to make the drawing incidentally or because there was a transfer of training from the one task to the other, but because the goal set up for him was not the guiding of his hand through the maze but the learning of the pattern in order that he might correctly trace the maze. When he had learned the pattern he could not only guide his hand through the maze but he could with equal facility make the drawing on the dots or even describe the path with nothing on which to mark. So-called incidental learning, then, simply means that the learner has a goal that

functions as well in one situation as in another rather than a more specific goal which can function in only one situation. The data unquestionably support the statement previously made that stimulation is the first essential to learning and that it is important not only because it initiates a response but because it sets up a goal toward which and only toward which learning proceeds.

VIII. The Original Pattern Reaction

Furthermore, whenever a goal is set up in any organized system an organized or patterned reaction toward the goal is initiated. When the trigger of a gun is pulled a definite series of actions follows, ending in the discharge of the bullet. In a constantly changing organism, such as a human being, it is not assumed that the response will be unvarying as in the case of a gun but it is asserted that given a particular stimulating situation and a particular condition of the organism the response will be as definitely patterned as in the case of a simple mechanical device. This is not a new idea. It is held by all those who depend upon the bond theory. It is a mistake, however, to assume that if the response is definite it will also be constant. It may be very definite in any given situation but never repeated since the organism, a fluid system, is not the same at any two moments.

In an intelligent adult the reaction may be in the form of an explicit and readily verbalized perception of a route to the goal, which may or may not be the best route, but which under the given conditions will be followed. If a mathematics teacher is asked how to square a number, he will reply immediately in an explicit and completely verbalized way, " Multiply it by itself." In a majority of situations, however, even with intelligent adults, there is not an explicit awareness of the route or even of the existence of a definite route and the individual says that he does not know why he acts as he does.

In an animal or even in an immature human being the perception of the existing organization must be very indefinite and lacking in explicitness but it seems preposterous to believe that in an organized system there can be any unorganized response. Chemical compounds and physical systems are known to react in

an organized or patterned manner. To say that a human or animal acts in an equally patterned manner does not deny that these latter are fluid and ever-changing types of organization while the former are relatively fixed, but it does assert that they are equally well organized even though their organization is being continually modified.

The fact that in the human being the pattern may be modified many times by internal and external changes before the goal has been reached has served to hide the fact that there exists in every reaction at any given moment a definite pattern. It is just this fact, however, that serves to distinguish learning-behavior from the non-variable reactions of inorganic systems. If we assume that the reaction is unorganized, we are led to talk of learning as random, chance, or trial and error, but if we assume that the reaction is organized, then we are compelled to say that all movements are directed toward a definite goal although that goal may not be the right one from the standpoint of the observer or from the standpoint of ultimate success, and although the goal is frequently modified before the response is completed.

That such is actually the case is demonstrated by the results of the present experiment. The stimulating situation, which determined the direction of the learning activity as has already been shown, set up a goal. That a definite path toward the goal was also present is equally apparent although in most cases the subject did not realize that he was acting on a definite plan. Thus subject QR2 reported, "I started out in a random, haphazard way"; subject WA1 reported, "When I first started I had no idea of a plan"; and subject RB3 said, "I didn't try out any plan at first." *But as shown in Fig. 3, regardless of the statements the subjects made, they actually did have patterned responses from the start.* Subject 2D2 entered the cul-de-sac at the right every time that he should have turned to the left, and not only that, but before he found the correct path, he spent as much as ninety-nine seconds in a cul-de-sac. In other words, whenever he came to a split-road situation, he turned to the right. Toward the end of the trial he apparently realized his mistake for, on the last cul-de-sac to the right, he spent only four seconds and

than went to the left through the ninth unit and on into the cul-de-sac at the extreme left, remaining there for one hundred twelve seconds. Subject 2C1 entered the first cul-de-sac to the left and then, apparently as a reaction, entered every cul-de-sac to the right even continuing right in one instance without turning downward. Subject 2A1 had a tendency to continue in whatever direction he had started. Other subjects showed other characteristics. Some, as 2A1, not only continued the same type of error

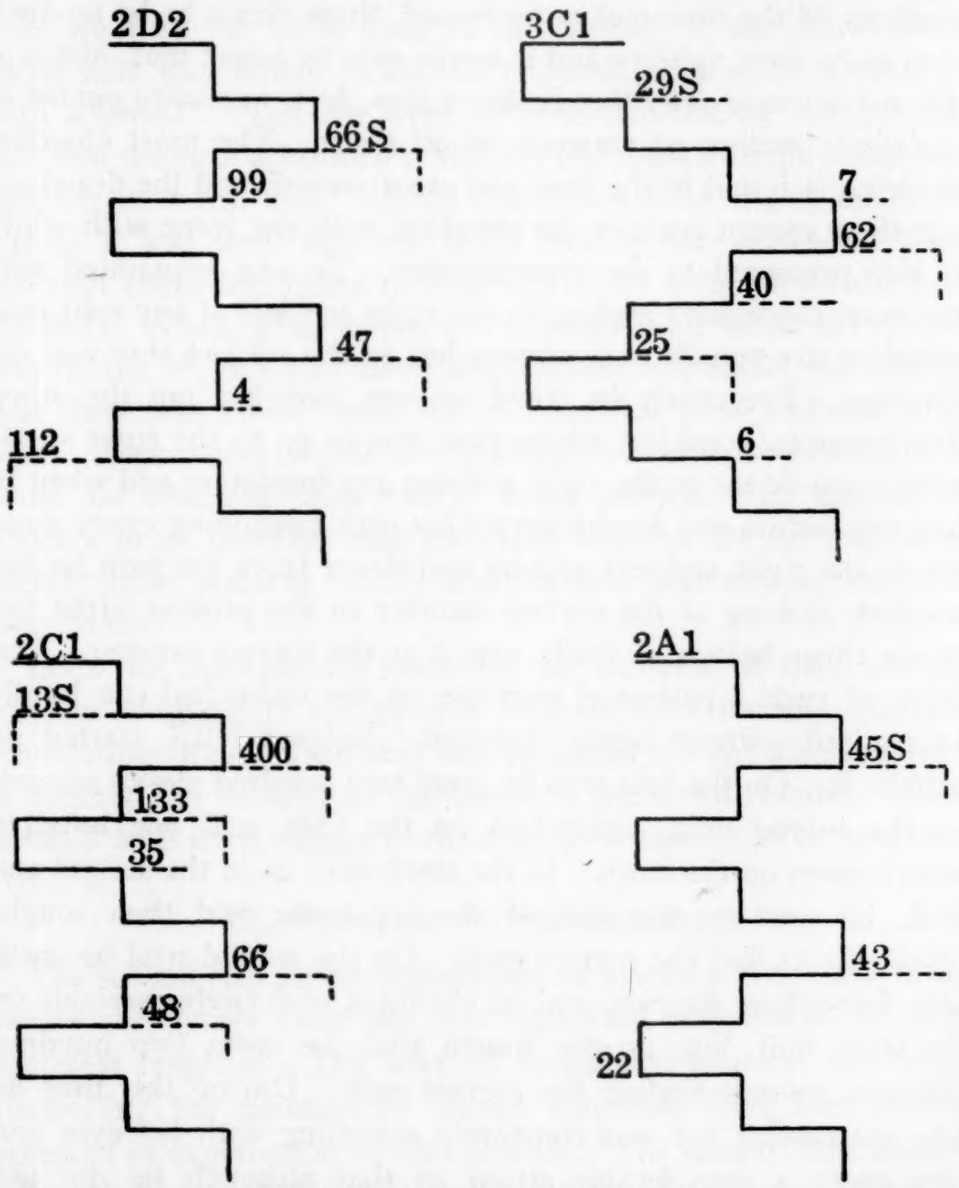

FIG. 3. Responses of Subjects 2D2, 3C1, 2C1, 2A1, Showing Patterned Responses and Pauses (S, Seconds).

to the end of the trial but repeated the same error for as many as six trials. In most of the subjects the original pattern was not so persistent, and the more rapid learner, as 2D2, changed his pattern before the end of the first trial.

With only the maze records to study, such statements as the above would be only conjectures, but with the drawings following each run on the maze and the comments of the subject as he worked to support the observations of the experimenter, and the analysis of the time and error record, there seems to be no question as to their validity and it seems safe to assert that, *although the subject may deny that he has a plan, he is in reality guided by a definite pattern of response at all times.* The most objective evidence is found in the time and error records and the drawings, but these cannot portray the situation with the force with which it was presented to the experimenter. To one acquainted with the maze the figures leading to the right and left at any split-road situation are equally conspicuous but to the subject this was not the case. Frequently he could see one path but not the other. For example, a subject whose plan was to go to the right would enter a cul-de-sac to the right without any hesitation and when he had reached its end would retract his path examining every number to the right and left and up and down from the path he had marked, looking at the correct number in the process often five or six times before he really saw it as the correct number. The force of such a patterned response on the individual can hardly be realized without being observed. Subject RBX started on pattern R. On the first trial he spent two hundred eleven seconds on the second unit, eighty-two on the fifth, and one hundred ninety-seven on the tenth. In the tenth unit, as in the second and fifth, he went to the end of the cul-de-sac and then sought repeatedly to find the correct path. On the second trial he spent only forty-three seconds, and on the third trial twelve seconds on the tenth unit, but, on the fourth trial, he spent two hundred fifty-one seconds finding the correct path. During this time he was not resting but was constantly searching with his eyes and was under a considerable strain so that although he did not become visibly nervous he perspired freely. In his search he

looked at the correct path time and time again but he could not see it until he finally obtained a correct idea of the path, and then he saw it easily and repeatedly.

Subject 3D3 spent about one-fourth of the whole time used on her first trial, on the last unit. She went into the cul-de-sac opposite the tenth unit and then, in her efforts to find the correct path, retraced her way and went into every cul-de-sac on the maze before finding her way into the tenth unit. One subject even went so far as to look at the bottom of the maze when about half way down, locate the 60, and put a circle around it with a pencil. Then she went on with her tracing but got the idea that the path continued to the left and went into the cul-de-sac opposite the tenth unit. Seeing that this was not right, she came out of it and went into the tenth unit as far as the 59 four different times but failed to connect the 59 with the 60 she had marked. When, after about ten minutes, and while her pencil was on the 59, she was asked why she did not finish, she replied that there was no 60 there but took another look and saw it at once. Experiences of this sort, although often not so pronounced, could be observed with nearly every subject. In general it appears to an observer that the rapid learners are the ones who modify their *patterns* readily and the slow learners are the ones who do not.

Both the observations made on the subjects as they worked and the evidence in the records indicate very forcibly that the stimulating situation not only sets up a goal toward which activity is directed but initiates in the learner a patterned response which persists until some change in the situation causes it to be modified.

IX. Progress in the Learning

The second step in the explanation of learning is to show what causes the change from the first organized response to the final adequate response. The laws of frequency, recency, and effect controlling the selection of chance responses have been widely accepted in explanation of this process. The data of this experiment show, on the contrary, that there is no unorganized or chance response and that a change from one organized response

to another depends not on chance but upon the perception of relationships. Two lines of evidence are present. Some factors that, if misunderstood, tend to cover up the perception of form will be first considered and then the direct evidence of the potency of such perceptions will be presented.

Objective form or pattern is obviously necessary in any maze or indeed in any situation but there is no guarantee that the form will be perceived alike by all individuals. In fact there is no such thing as objective form except under instructions to organize the form on some given basis. Objectivity is not inherent in a situation but is the result of the acceptance of a conventional way of looking at a thing. It is, therefore, not surprising that the assumption of an objective form by the experimenter is an important source of confusion. If the path is looked at as ten equal units varying only in the order of the changes in direction of the horizontal lines, then pattern 2 which is two units to the right, two to the left, and so on, should be the easiest. Actually, one subject reported at the end of the first trial that this pattern went "every which way", while another reported the irregular pattern Q "lots easier than the rest". Time and error data showed that one pattern was about as easy as any other.

In Groups A, B, C, and D the external factors were controlled as rigidly as possible except for the visibility of the pattern and the objective form or organization of the path. The results, when the different patterns are compared, show more striking individual differences than pattern differences. About as many completed their first pattern in one period on one pattern as on another except for pattern W, which was completed by ten as compared to six and seven on the others. In the number of trials needed to complete the first pattern the order is reversed. In the time spent learning the first path pattern 3 ranks lowest with W and R about equal and 2 highest. The introspective reports show that each pattern was reported hardest by some and easiest by others of the group.

Compared to these slight and inconstant differences between patterns there is a large individual difference. The average number of trials on the first pattern learned varied from 6.2 on pattern

3 to 10.1 on pattern W, but the individual range was four to ten on pattern 3 and five to fifteen on pattern W. Compared to other factors present it must be concluded that the objective form is of slight significance. The explanation is that the experimenter did not take his subjects into his confidence and agree upon a particular way of looking at the pattern so that all would perceive it as composed of units consisting of a horizontal line followed by a vertical line. As a result few actually did perceive it in that way. Subject WA1 said that pattern W " zigzagged down three times and then came back to the middle ". Subject 2F2 remembered the direction of the horizontal lines as 4–2–1–3. Subject 2F1 saw this pattern as a stair-step effect and pattern R as " two projections on this side and two on the other, then one on the first ". In each case what was seen depended in part, of course, upon the external situation but largely upon the individual and not at all upon what the experimenter saw. When this is taken into consideration, it seems that one should expect that ease of learning will not vary with the supposed objective form but will depend upon the perception of the subject. In this experiment as in actual life situations, past experiences and present expectations determine to a large extent the organization that an individual makes in any situation, but it is always just this perception which he actually makes and not anyone's else description of the external situation that determines the adequateness of his response. When it is fully realized that the individual's behavior can be explained only in terms of what he tries to do and not in terms of what an observer thinks he should do, one of the greatest sources of error in the interpretation of learning experiments will have been eliminated.

Visibility supposedly decreases in Groups D, C, B, A, and G in the order given, Groups D, B, and G being most strictly comparable on account of having the same instructions concerning the drawings. In Group G only one of the three, in Group B six of the twelve, and in Group D nine of the twelve subjects completed the task in the time allowed. The order is the same for the average length of time used to learn the maze: G–51,392, B–42,535, D–28,052 (30ths of a second). In all respects A

and C rank very close together, usually between B and D. On the other hand the range of the number of trials within the groups is from seven to twelve which is two to three times as great as the difference between the most widely different groups; and the range in time is from one to two times as great as the difference between the most widely separated groups. Apparently then, visibility of form does have an influence on the speed and efficiency of the learning but *only when the increased visibility makes the perception of a form easier.* When the supposed increased visibility obscures the form which the individual would most easily perceive, it is a hindrance. Or it might be better put by saying that increased visibility from the experimenter's point of view does not insure increased visibility for the learner.

X. Problem of Individual Differences

Individual ability is often set forth as one of the important factors in learning. If it is, how does it work? Since the terms intelligence and individual ability mean vastly different things to different people, it is impossible to make a categorical statement. In this experiment two measures of ability were available: the ranking on the Freshman psychological examination and the number of grade points earned during the first three semesters in college. That these do not measure the same thing is shown by the correlation of .40 between them.

On the basis of their ranking in the psychological examinations, the subjects were divided into five groups: group one including the upper 20 per cent; group two the next 20 per cent, and so on. In the per cent who completed their first pattern in fifty minutes, in the average number of trials, and in the length of time spent in learning the first form, the middle group excelled all of the others, but the difference in number of trials between this group and group one is only 1.9 while the range in number of trials in each group is from nine to twelve or from five to six times as great. The range of times within each group is also several times the difference between the most widely different group averages.

The subjects were also ranked according to the number of

honor points earned. Group one included those with an average of two or more points; group two those having from 1.5 to 1.9 points; group three from 1 to 1.4 points; and group four all of those with an average of less than one honor point. The percentages of the groups who completed the first pattern in fifty minutes rank in the order 1–3–4–2: group one having 82 per cent; group two, 55 per cent; group three, 67 per cent; and group four, 58 per cent. Ranked according to the average number of trials on the first maze pattern, the order is 2–4–3–1. Ranked according to the amount of time used, the order is 3–1–4–2. On the other hand the greatest difference in number of trials between group averages is 3.6 but the range within a group is two to three times as great. Whatever effect individual ability as measured by the Freshman psychological examination and by the earning of honor points may have on the learning, it cannot be of primary importance in view of these results, since the group differences are neither large nor consistent. Perhaps the best statement is that individual ability of a general nature is not helpful *per se* but only when it contributes to whatever may be the crucial factor in the learning.

The above statement regarding the lack of influence of general mental ability does not imply that individual differences are not important. The data show that they are much more striking than any group differences that have been discovered. Certainly the past experiences of the individual play an important part in his learning. Subject RB2, who saw a resemblance in pattern 3 to an English castle, was able to make a correct drawing of the form in one trial although on her second and third patterns she used three and four trials, respectively, involving 712 and 661 seconds compared to 204 seconds on the "English castle" pattern. Subject 2A1 who had some engineering training learned the first pattern in five trials and each of the succeeding patterns in one trial. He said he learned the formula for each pattern and as a result, in learning the four patterns, he made only four errors in his drawings, two in order of turns and two in proportions of a step. What an individual perceives certainly is an outgrowth of past experience (but not caused by it).

The goal that is set up is another factor that determines to a large extent what the learner sees. When the subject had the goal of running through the maze, he often did not notice relations but learned the general form of a unit or cul-de-sac and glanced quickly at its farther end before entering to see if there was a way out. Such a learner was soon able to go through the maze quickly and without error but knew nothing of the form except the general direction and the size of the units. Other subjects, with the same external situation, had the goal of learning the form so that they would know the way through the pattern, and as a result, they knew all of the necessary relations in the form before making a correct run. What the goal actually was for any subject can be determined only by the drawings. Subjects 2A1, 2A2, 2A3, RC1, and 3A3 had all or nearly all of the units wrong in size on their first drawings and had very little idea of the order of turns although each had made a run correctly and without hesitation before attempting a drawing. On the other hand, RA1 and RA2 had a goal of learning the form or organization, for the former had all the form entirely correct and the latter both form and size of all units correct on the first drawing, although both had received exactly the same directions as the subjects mentioned above.

A further evidence of the influence of goal on perception is supplied by Group E whose members were told to watch for a form. One member of this group learned the four patterns in four trials and no member used over eight, whereas, except for the members of Group F, who were given time to look over the completed form, only three other subjects completed the four patterns in as few as eight trials and the average for those not given the special instructions was sixteen.

A third individual factor is the persistence with which the individual retains the original patterned reaction. As previously shown, some subjects modify their plan before the end of the first trial while others retain it almost intact for many trials. Examples of the latter are 2C1 who, in the sixth trial, retained four of the seven original errors, and 2C3, who in the tenth trial made three of his original errors. Again, subjects vary not only

in the readiness with which they make changes, but in the amount of the change. Some modify their plan only enough to include the new perception while others consciously revise their whole plan with every new idea, often improving in one respect but making their procedure less effective at several other points. In directing the progress of learning the general level of ability seems to be of uncertain significance but the state of maturation of the individual and the existing interrelations between the individual and the external situation determine both the goal that is set up and the set of relations or the organization that the learner will see in the situation. This and the readiness with which the learner shifts from one perception to another certainly do influence the progress of the learning.

XI. The Problem of Imagery

The type of imagery employed in the attack upon the problem was found by Warden (11) and Husband (4) to be closely related to individual differences in the learning. Both writers asked their subjects to report whether they used a word reaction, visual imagery, or a motor method of attack. They found significant differences between the groups into which the subjects classified themselves as to average number of trials, range of trials, and, in the former case, as to intelligence scores as measured by the Army Alpha and Thorndike tests.

In the present experiment subjects were not asked to place themselves in any category but to describe how they learned the patterns. No subject, with the single exception of one who learned blindfolded, failed to notice some relationship in verbal terms. The extent of the verbalization varied all the way from a simple wording of the relationship of four over and two down to a complete formula for the whole path and varied in importance from being merely a check on the visual image to being the sole basis for the reproduction of the path. In all but nine cases, the verbalization was accompanied by a visual image which might be anything from a vivid picture of the whole path to a vague image giving only a general idea. In many cases the visual image gave the general form while the details were remembered verbally.

Fifteen of the sixty subjects who completed the paper maze reported some form of kinaesthesis. In some cases this was fleeting and uncertain but subject WC2 reported that when she started out all she needed to do was to keep going for "the pencil knows which way to go" and subject 2H3 reported that she made errors only when she tried to be guided by her eye instead of by "the feel of it". Twenty-three reported that they memorized at least a part of the numbers on which changes of direction were made. Several commenced by remembering key numbers but after once "seeing" the pattern abandoned the memorization of numbers. Twenty-seven reported the use of other orientation guides; some located the end; others remembering how close to the edge of the maze to go before changing direction; and others dividing the path into right and left or first and last halves. In some cases these orientation points were a part of the primary memory scheme while in others they merely served as a check on a visually or verbally remembered path. From this it appears that the memory image involved in the learning of a maze is not a simple affair but a complex of many methods varying in their combinations and in the relative importance of the different factors.

On the basis of the working of a simple multiplication problem designed to test the dominant mode of imagery, the subjects were divided into four groups: visual, verbal, visual-verbal, and visual-kinaesthetic. The differences between groups were not as striking as those found in the experiments referred to above. Differences in the per cent who finished the first pattern and in rank in the psychological examination are insignificant. In the number of grade points earned the visual group stood twice as high as the visual-kinaesthetic, with the other groups intermediate. Ranked as to number of trials, the visual group held the best record with the visual-verbal second, and the visual-kinaesthetic last, but the difference between the first and last was only 4.4 while the ranges of individuals within the groups ran as high as 11. Such differences indicate that the type of imagery is of itself not highly significant although it may play an important part in furthering perception.

XII. Frequency of Response

Frequency of response does not insure continuance of the response. This is best shown by an inspection of the individual data sheets. Subject 2R2, for example, committed each of three errors four times in succession yet on the fifth trial dropped all of them. Subject RA2 went into the cul-de-sac opposite the ninth unit four times in succession but in the succeeding four trials did not make this error once. Subject 2C1 entered the cul-de-sac opposite the third step the first three trials and the one opposite the seventh step the first seven times but in both cases changed suddenly to the correct movement and never returned to the old, frequently-performed act. On the other hand, all except the best learners show instances where the correct path has repeatedly been followed past a cul-de-sac and then when a new idea has been perceived the cul-de-sac is suddenly entered. A still more striking case is that of 2A1, who, on his fourth form, followed the cul-de-sac opposite the ninth unit and then made a tenth unit in the right direction, but, since it was at the end of a cul-de-sac, entirely off the correct path. He began this error on his first trial and continued it without hesitation through seven more trials. If frequency of response is important, he should have continued to make this response indefinitely since the instructions did not indicate that he should stop when he had the correct form. On the contrary, in his ninth trial he suddenly hesitated, saw the correct path, and changed to it immediately and permanently. Thus, while frequency of response is shown not to be the cause of the learning, frequency of stimulation is at least a contributing factor since it leads to perceptions under varying conditions and finally to successful perception that enables the learner to make an adequate adjustment.

XIII. Perception of Form

It has been shown that the learning process is initiated by a stimulating situation which sets up a goal and that the fact of organization in the individual necessitates that the reaching of the goal be by a definite path. It is not meant to imply by this that

the individual has a preformed pathway along which nerve impulses travel, setting off muscular and glandular responses, but that the individual, a completely organized structure, can and must respond in accordance with its organization. Illustrations of the kind and importance of the organizations of behavior first elicited by stimulation in the present experiment have been given. It yet remains to show how progress takes place from the first organized response to the completely differentiated and appropriate response which actually enables the individual to reach his goal and which is the end result of the learning process.

The observational, introspective, and objective data already shown support the conclusion that such *progress takes place by perception of form or organization in the situation and only by that means.* Such a perception of form may involve the perception of a completely organized and adequate form all at once or it may consist in the perceptions of relationships of varying degrees of generality, one at a time. In any case it appears that the original pattern of reaction is persisted in until some new perception enters in to change or replace it, and this is true regardless of whether the new perception is better or worse than the old from the standpoint of reaching the goal, regardless of whether it is in the form of a completely verbalized response or of a kinaesthetic or visual image, and regardless of how many times the former response has been repeated. The learner may or may not be able to state that he has made a perception and be able to describe his perception in words. Subject 3B2 stated, for example, on her fourth drawing, that she had no idea what to do and that it was just the same as at the beginning, only worse. Her drawing, however, had six of the ten turns correct and two of the ten units of the correct size, whereas her first drawing had only six units all of which were wrong in size. Subject 2H3 could draw more correctly if she did not pay too much attention to her drawing. Nevertheless, the most valuable perceptions from the standpoint of using them in varying situations are the explicit ones. For example, subject WA3, near the end of the ninth trial, suddenly smiled and said, "I believe I woke up". Her next drawing was correct although the previous one had two

extra units and only one of the twelve was of the correct size. Both Peterson (7) and Heron (3) noticed the difference between explicit and implicit perceptions. The latter states that the subject "arrives at a generalization by which he can run the maze without further difficulty and without accurate knowledge of the details of the pattern", and the former found that subjects "learn both consciously and unconsciously to follow a simple rule". Scott (9) says that "frequently the pattern functions non-consciously". These statements are in entire agreement with the findings of the present experiment. Identifiability and explicitness may be useful but are not necessary characteristics of a perception of form or of progress in learning.

It has been shown that the various factors associated with the learning process are effective in furthering it only as they modify the perception of form by the learner. It appears further that elimination of errors depends upon perception of form and not upon a tendency to eliminate useless movements as has frequently been assumed. The evidence is two-fold. In the first place, before the pattern becomes differentiated by detailed perceptions of organization, the drawing will usually tend to follow the shortest route to the goal and will lack many details. Here the learner's tendency is not to eliminate useless movements but to eliminate all movements possible in order to reach the goal. Again, subjects like 2C1 and 3C1, having once found the goal, resist very strongly going in a direction away from the goal. Elimination is made not of useless movements but of any movements not clearly perceived.

Direct evidence also exists to show that the elimination of errors results from perceptions of form. If chance governs the elimination of errors they should be eliminated in chance order but such is not the case. Errors are usually eliminated in groups. Comparison of elimination of errors and the drawings shows that elimination of errors follows the perceptions of relations in the path and that the introduction of errors follows the perception of incorrect relations in the path. That is, when a subject makes a run through the maze and shows by his drawing that he has misapprehended the direction he took, the next run of the maze

shows an error in the direction of his misapprehension. Subject 2R2, for example, after the second trial, retained three horizontal and three vertical errors but eliminated all of the horizontal errors after the fourth trial and all of the vertical after the third trial. Subject WC2 eliminated three persistent errors in the fifth trial and subject WC3 eliminated three in the sixteenth trial.

Finally, the progress of learning as indicated by changes in time consumed, corresponds with modifications in the perception of form. The evidence on this point is threefold: observational, introspective, and objective. The experimenter was frequently impressed by the suddenness with which an idea came to a learner as evidenced by a sudden expression of alertness, a sudden change of procedure, or by the spoken words of the subject. In addition to these observations and the introspective reports of the subjects, the data on time and errors show that time elimination was not by gradual increments but by sudden drops. If only the total time for the trial is considered this is not apparent, as the fluctuations in the unlearned portions cover up the drop in the learned section. The work of subject 3A2 is typical and is shown in Fig. 4. The curve for the pattern as a whole, if the steeples are smoothed, approximates a chance curve but, if the curves for the separate units are considered, it is apparent that the former is misleading. Unit one gave no trouble. The second unit was traversed rapidly until the third trial when, probably as a result of overconfidence, an attempt was made to turn down too soon. Following this mishap, the cul-de-sac opposite the second unit was entered on the fourth trial, involving a delay of ninety seconds. After this experience the second unit was learned and gave no further trouble. Unit three continued in the same direction as unit two and gave no real trouble. Unit four is the last of three units to the right. The cul-de-sac was entered here on the second and third and again on the fifth, sixth, and seventh trials. This shows as two distinct steeples and might indicate that the turn was learned once and then forgotten. Such is probably not the case for on the fourth trial the subject, after spending ninety seconds in the cul-de-sac at the extreme left, went unhesitatingly to the right when he got out, not only passing the cul-de-sac

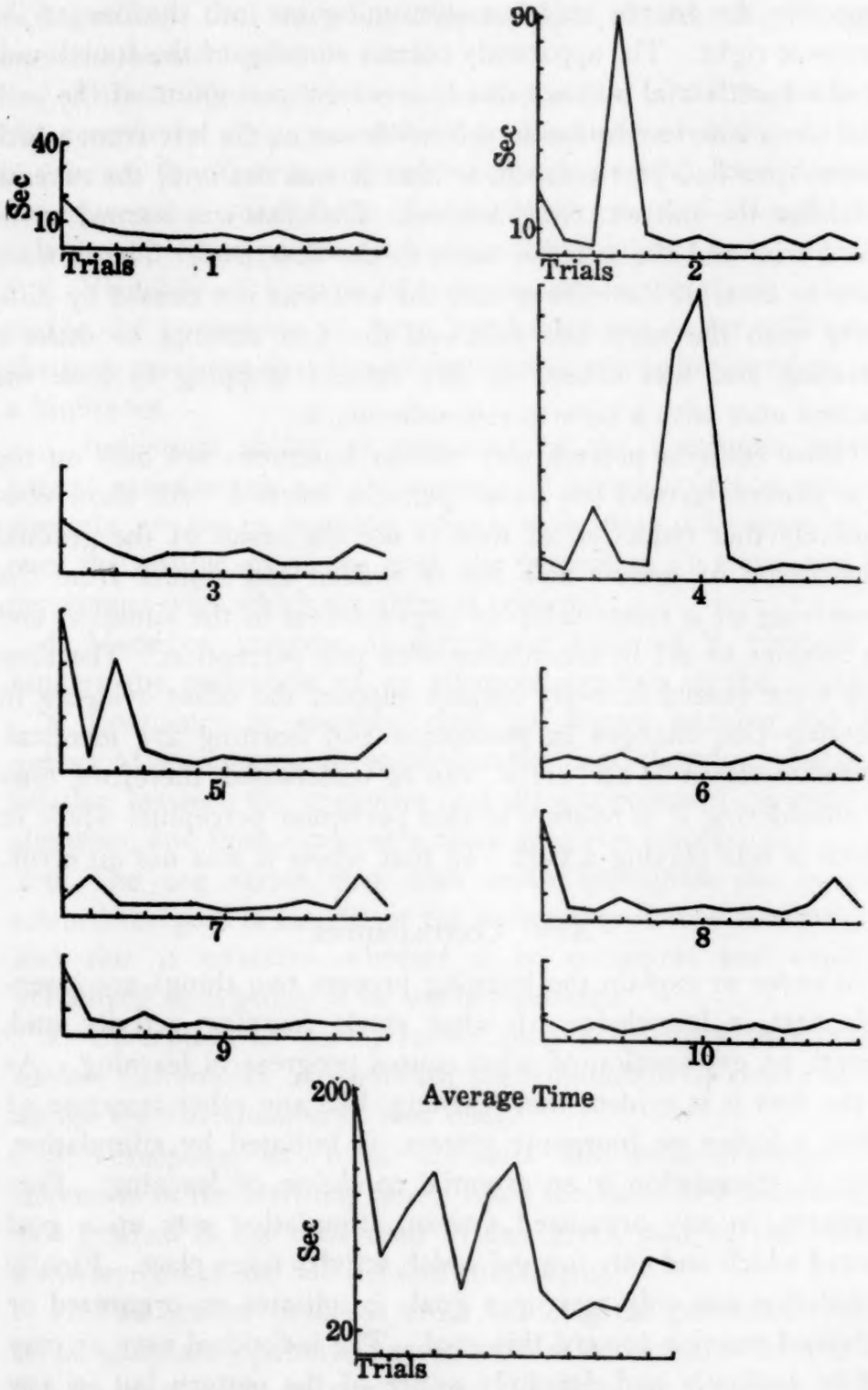

FIG. 4. Unit Curves for Subject 3A2.

opposite the fourth unit but continuing on into the one at the extreme right. The apparently correct running of the fourth unit in the fourth trial was not due to a correct perception of the path but was made in relation to the cul-de-sac at the left from which the subject had just escaped, so that it was not until the seventh trial that the unit was really learned. Unit five was learned in the third trial and the last five units in the first trial. The upward turn in most of the curves near the end was not caused by difficulty with the units but followed the first attempt to make a drawing and was caused by the subject stopping to look the pattern over with a view to remembering it.

Other subjects present very similar situations not only on the first pattern learned but on all patterns learned. All show conclusively that reduction of time is not the result of the gradual elimination of useless acts but is sudden and results from the perceiving of a relationship or organization in the situation and an attempt to act in accordance with this perception. The time and error record in every respect support the other evidence in showing that changes in perception and learning are identical. The elimination of an 'error' can be understood, therefore, only by considering it in relation to that particular perceptual whole in which it was playing a part. In that whole it was *not* an error.

XIV. Conclusions

In order to explain the learning process two things are essential: first, a knowledge of what starts learning activity and, second, an explanation of what causes progress in learning. As to the first it is evident that learning, like any other response of either a living or inorganic system, is initiated by stimulation. That is, stimulation is an essential condition of learning. Furthermore, in any organized system, stimulation sets up a goal toward which and only toward which activity takes place. Finally stimulation not only sets up a goal; it initiates an organized or patterned reaction toward this goal. The individual may or may not be explicitly and definitely aware of the pattern but in any case he acts in accordance with it.

Regarding the second problem, that of learning proper, several statements may be made:

1. Objectivity is not inherent in a situation but is the result of the acceptance of a conventional method of perceiving a form and hence is effective only with individuals who have accepted the convention. Simplicity of objective form is of aid only if it aids the subject to perceive a form in the situation.

2. Visibility of form is of value in the learning only when it makes the perception of form by the subject easier. When it obscures the form that the subject would otherwise perceive, it is a hindrance.

3. Individual ability as measured by the Freshman psychological examination and the earning of honor points is not consistently an aid in learning. Such individual differences influence the setting up of the goal, the perception of form, and the persistence with which the form is retained.

4. Mode of imagery is significant only as it furthers or hinders the perception of an adequate relation in the situation.

5. Frequency of response does not insure learning but frequency of stimulation allows maturation, and therefore change of relation between the organism and the environment, to enter the situation, and thus produces a more adequate perception.

6. The one factor that does make intelligible the progress toward the goal is insight or the perception of new relationships, and this is effective whether it be conscious and explicitly verbalized or whether it be undifferentiated.

7. Perception of form, rather than a tendency to eliminate useless movements, accounts for the elimination of errors as well as for the introduction of new ones.

8. Perception of form accounts for both increases and decreases in the learning time. Such increases and decreases are not gradual if the time used in any given part of the maze is considered, but are sudden and permanent.

9. The learner proceeds from the original patterned reaction to an adequately patterned reaction, that is, he learns by and only by the perceptions of new relations within the situation. He is expanding and differentiating a unified response.

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A STUDY IN THE RECALL OF PERCEIVED RELATIONS

by

CREE WARDEN

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I. INTRODUCTION

The problem of this investigation was suggested by a monograph entitled "Recall as a Function of Perceived Relations", by Cora B. Key (1). In this monograph Dr. Key reports a statistical study of the learning and retention of material, principally of the type of the paired-word associate. Inspection of those pairs which were more easily learned and recalled during the course of experimentation indicated the presence of four factors: (1) clarity of the relationship, (2) identity of the meaning of the terms, (3) interdependence of the meaning of the terms, and (4) lack of interfering terms. Dr. Key devised a scheme to secure a list of word-pairs which would exhibit these factors in graded amount and found that the average number of pairs learned and retained for each grade was fairly constant and positively correlated with the predicted position of the grade in the series.

II. PURPOSE AND METHOD

In this study we proposed to subject these factors to further experimental testing. More particularly, we wished to determine the effect on learning and retention of systematically varying the nature of the interdependence of the meaning of the terms. It was anticipated that such a study might reveal further evidence

not only for the existence of a relational factor, but also for the manner in which it operates.

The nature of the relationship between the associates could be more readily controlled, we believed, if it were possible to give it a logical as well as a psychological interpretation. Accordingly, five categories were selected which, by inspection and preliminary experimentation, gave fairly unambiguous relations. They were designated as follows: (1) synonyms (jeer—scoff), (2) antonyms (clean—dirty), (3) object-attribute (fox—sly), (4) whole-part (box—lid), and (5) cause-effect (germ—epidemic).

Experience in constructing word-pairs to represent these categories indicated a tendency to use very common words for some, and more unfamiliar terms for others. In order to obviate this tendency as far as possible, practically all of the words used in this study were taken from Thorndike's list of 10,000 common words, but none from his list of the 500 most common words (2).

After a pair had been constructed and classified by the experimenter it was presented to a group numbering about 54 college students, on the average, who were asked to write a sentence or two expressing the meaningful connection between the two words. The percentage of subjects responding favorably to each pair was used as a measure of its clarity and definiteness. Twenty of the best pairs standardized in this manner were retained for each category. The average "classification value" was about 90 per cent.

Four experimental lists were prepared by selecting five pairs at random from each category, making a total of 25 pairs for each list. As far as could be determined by inspection, no pairs were allowed to remain in the same list which might lead to a confusion of terms. Three orders were prepared for each list for use in presentation, immediate recall, and delayed recall.

In order that the pairs could be seen by a fairly large group, they were prepared for presentation by pasting black letters ¾ inch high on a white card 7 by 11 inches. The words were centered on the card with the second member of each pair below the first. For recall, the letters forming the first member of each pair were pasted on the opposite side of the card.

The apparatus consisted of a black screen with a window through which the cards could be seen. Holes were punched at the top of the cards so that they could be suspended from two horizontal rods back of the screen. By the use of a stop-watch and stiletto the cards could be dropped in succession after being exposed for the desired interval.

The procedure was as follows: After the instructions had been read, each pair was exposed once for an interval of 5 seconds; the exposures followed each other in immediate succession. Soon after the presentation, protocols were secured by asking the subjects to write one member of the pair upon seeing the other. The response was always to the first member of the pair although the subjects were not definitely informed of this fact. Ten seconds were allowed for each response. The protocols for delayed recall were obtained in a similar manner one week later. The subjects expected a delayed recall, but were not told definitely when it would occur.

Each experimental list was presented to groups of college students averaging about 50 in number. No group responded to more than one list. The subjects were urged to regard each pair as a separate lesson, to confine the learning to the interval during which each pair was exposed, and to respond from their own individual memory in recall. The records of those subjects who were not present at both experimental periods were discarded.

The protocols were scored for both accuracy and relationship. In scoring for relationship, a response was considered correct if it indicated with reasonable certainty that the subject had grasped the relation intended by the experimenter.

The two principal measures employed in comparing the categories were designated as the "immediate recall value" and the "relative recall value". The former is the ratio of correct responses secured for each category immediately after presentation to the number of correct responses possible for that category. The latter is the ratio of correct responses secured for each category one week after presentation to the number of correct responses obtained immediately after presentation for that category. All ratios were expressed in the form of per cents.

It will be convenient in discussing the results to assume that the immediate recall value measures the degree of learning which has taken place, and that the relative recall value measures the degree of retention. However, evidence will be presented later which indicates that these assumptions are not strictly true.

III. Results

The results are summarized in Table I. The values were computed by averaging the corresponding measures obtained from each of the four experimental lists. Although measures of reliability were not computed, there can be little doubt regarding the statistical significance of the differences in extreme cases at least. By comparing the values obtained from the two methods of scoring it can be seen that those measuring relationship are larger in every case. It can also be noted that the differ-

TABLE I

Major experiment

Immediate Recall Values

Accuracy			Relationship		
Category	%	% Diff.	Category	%	% Diff.
w.–p.	89.8		w.–p.	90.8	
		4.3			2.0
o.–a.	85.5		o.–a.	88.8	
		4.9			1.0
c.–e.	80.6		c.–e.	87.8	
		4.1			4.8
ant.	76.5		ant.	83.0	
		9.6			7.9
syn.	66.9		syn.	75.1	
		22.9			15.7

Relative Recall Values

Accuracy			Relationship		
Category	%	% Diff.	Category	%	% Diff.
w.–p.	93.9		ant.	94.8	
		1.8			0.3
ant.	92.1		w.–p.	94.5	
		5.1			3.3
o.–a.	87.0		syn.	91.2	
		1.6			0.5
syn.	85.4		o.–a.	90.7	
		6.2			7.6
c.–e.	79.2		c.–e.	83.1	
		14.7			11.7

ences between the categories were reduced in the majority of cases when the data were scored for relationship. There was a lack of correlation between the ease with which the pairs representing a category could be learned and that with which they could be retained. The relative position of the categories for either learning and retention, however, varied little for the different methods of scoring.

IV. Check Experiments

A number of check experiments were performed in an attempt to answer some of the questions raised by the major experiment. In the most important of these we wished to determine the effect on retention which resulted from making the ease of learning the pairs as nearly equal as possible. The immediate recall value of each individual pair was calculated, and a new experimental list was prepared by selecting five pairs to represent each category which had such an immediate recall value as to make the averages for the different categories nearly equal. At the same time, the pairs were chosen from among those which had the highest classification values. This list was presented to a new group of 54 college students. The procedure was practically the same as that used before. The results of this experiment are recorded in Table II. It will be noted that the differences between the immediate recall values of the categories are less than those obtained before while the differences between the relative recall

TABLE II

Check experiment

Immediate Recall Values			Relative Recall Values		
Category	%	% Diff.	Category	%	% Diff.
w.–p.	84.1		ant.	98.1	
		0.0			2.1
o.–a.	84.1		w.–p.	96.0	
		7.8			7.7
ant.	76.3		syn.	88.3	
		3.0			9.9
c.–e.	73.3		o.–a.	78.4	
		0.3			3.7
syn.	73.0		c.–e.	74.7	
		11.1			23.4

values are greater. The relative position of the categories with reference to ease of retention is the same as that obtained in the major experiment when the data were scored for relationship.

A phenomenon which was noticed in the major experiment but more definitely analyzed in the one under discussion was the appearance of correct items in delayed recall which were either omitted or incorrect in immediate recall. This phenomenon is probably that known technically as " reminiscence "(3, 608–610). Over 16 per cent of the subjects in this experiment made a better score in delayed recall than in immediate recall. Moreover, the phenomenon occurred in differential amounts for each category. The order of the percentages of persons responding with more items in delayed than in immediate recall, from largest to smallest, was about the same as that for the relative recall values. These facts indicate that the immediate recall value is not an adequate measure of the amount of learning which may occur after the presentation. Furthermore, it appears that the relative recall value is not a simple measure of retention but represents a balance between items lost, retained, and gained.

In several check experiments an attempt was made to analyze the factors which made some of the antonyms and synonyms apparently so difficult to learn. In one of these, the antonyms and synonyms were separated. Two lists were selected in which the pairs representing the whole-part, object-attribute, and cause-effect relations were the same, but antonyms were included in one list and synonyms in the other. The fact that the antonyms and synonyms were as hard to learn as before indicates that the mere presence of these categories in the same list probably does not affect the ease with which they can be learned. However, inspection of the types of error reveals a tendency to confuse those terms in which the ideas expressed by the pairs are somewhat similar. For this reason the measures of recall are undoubtedly to some extent a function of the entire list. This factor is probably of some importance in accounting for the fact that the immediate recall values in the check experiment discussed above were not as nearly equal as might have been expected.

V. Explanation of Results

Preliminary experimentation with a different set of associates as well as a check experiment with the set used in this investigation indicates that the immediate recall value of a pair is conditioned to some extent, either directly or indirectly, by the 'commonness' of the terms used. This is especially true of antonyms and synonyms. Inspection of the pairs discloses that antonyms and synonyms are composed largely of adjectives and verbs while at least the first member of the other three types is usually a noun. We suggest that when the attempt is made to control the commonness of the terms as measured by Thorndike's scale that the adjectives tend to become abstract at a faster rate than the nouns and that it is this factor which made some of the antonyms and synonyms so difficult to learn. This explanation is supported, indirectly, by introspective data in which it is evident that the better learners tried to envisage every relation in a concrete situation.

We have been unable to account for the results of this study by any theory which relies on the formation of mechanical associations in the nervous system. The conditions of the investigation considered as important in the work with nonsense syllables can hardly account for the variability in the functional strength of the associations classified under the various categories. Such factors as contiguity or simultaneity, frequency, length of material, ordinal position in a series, and recency were practically the same for all categories. It seems necessary to assume, then, that immediate recall measures the relative strength of 'connections' *already formed.*

The chief difficulty arises when we try to account for the apparently changed variability in the strength of these 'connections' at the time of delayed recall. The external conditions were approximately the same during the two recalls. And it is difficult to see how any change in the health or attitude of the subjects could influence the response to the categories unequally and in so much the same manner from group to group.

It might be supposed that the associations were of different

ages and that, following Jost's law, the single repetition increased the strength of the older 'associations' more than that of the younger ones. Since the connection between antonyms is apparently strengthened more than that between the pairs of any other type, it should follow that they are the oldest. But it has been found that children respond less frequently with antonyms than with other types of associations (4). Hence, the possibility of using this law is precluded.

Retroactive inhibition might account for the change in the rate of forgetting some pairs. For instance, the interpolated activity between the presentation and immediate recall involved 'light' conversation. Cause-effect pairs were retained fairly well because the interpolated activity was quite dissimilar. After the immediate recall, regular class work was resumed which, presumably, was of a more causal nature. Hence, retroactive inhibition would operate in such a way that the cause-effect pairs were forgotten quite rapidly.

But, while this factor might account for the variability in the rate of forgetting the words of some categories, it is difficult to see how it could explain the appearance of reminiscent items. For this, quite a different factor seems necessary—a facilitating rather than an inhibiting process. A memory review could hardly be supposed to occur unless an item was originally remembered. And, furthermore, the phenomenon occurred with subjects who could have had no possible motive for disregarding the instructions concerning communication.

The principles enunciated by Spearman (5), if not entirely adequate for our problem, have the merit of making it possible to recognize the importance of such relational factors as those pointed out by Dr. Key. The paragraph most relevant for our purpose is the following (p. 146): "Suppose . . . that any person has at some previous time apprehended any two items as mutually related. Consider what can ensue when the same person happens to present to mind one of these two items again, but now alone. As the immediate result, the previously presented relation may be re-evoked: and for this purpose, nothing can possibly serve except a process of reproductive kind. But when once this

much has been effected, then *either* a reproduction, *or* an eduction, or both coincidently, can proceed to re-evoke the other of the two previous items."

It has been suggested that these principles be applied somewhat as follows. Suppose that the immediate recall values measure the extent to which the relationships of various types were recognized. The fact that the relative position of the categories in immediate recall is the same for both methods of scoring bears out this point. It would seem, then, that the production of correlates in immediate recall is largely dependent upon reproductive processes.

In delayed recall, the fact that the differences between the categories are considerably reduced, when the data were scored for relationship, supports the contention that the relations were retained and reproduced with about the same degree of facility. We must assume, however, that the production of correlates during this period is largely dependent upon 'eductive' processes. These processes are of a more selective or inferential sort than the ordinary 'associative' processes. Presumably, such a process would operate with the greatest effectiveness where the alternatives are fewest in number. This would seem to be true in the case of antonyms. Most words have only one or a few antonyms. In the case of the object-attribute relationship, on the other hand, any one of a number of attributes might be educed. The chances, then, would be more favorable for the selection of the correct antonym than for that of the correct attribute. If this held true in proper degree for the other categories we could account for their positions in relative recall value.

The chief difficulty with the above explanation, theoretically, is that of understanding why the reproduction of a relation should be more stable than the reproduction of a correlate. In other words, why were the pairs of all categories, once learned, not retained equally well thus making the use of the 'eductive' processes unnecessary? Furthermore, how shall we account for the appearance of reminiscent items? Why should a correlate be educed correctly in delayed recall which was not reproduced, or reproduced incorrectly, in immediate recall? If it is supposed

that both eduction and reproduction work together in delayed recall to bring about this result, why were they not both equally effective in immediate recall? It would seem that more dynamic processes are needed which will account for all the phenomena in a less disjointed manner.

Gestalt or organismic psychology has much to say about such processes. Psychologists of this school repudiate any analysis into parts or processes which renders their interaction incapable of being explained. Moreover, such a phenomenon as that of reminiscence is not extraneous to the system, but is regarded as typical of the nature of all learning. We may, therefore, attempt to apply organismic principles with some hope of resolving our difficulties.

The theory suggested is, essentially, that the presentation of each associate tends to initiate a psychophysical *Gestalt* or configuration. During the recall periods, the presentation of one member of the pair tends to reactivate this configuration and lead to a 'closure' in the form of the correct response. The immediate recall values of the categories, then, measure the chances which the pairs representing them have of producing configurations which operate effectively at this time. The relative recall values of the categories measure the chances which the pairs representing them have of producing configurations which either maintain or improve their effectiveness during the interval between the two recall periods.

It has already been intimated that the formation of a configuration is facilitated if it lends itself to the imagination of a concrete situation. We may understand this, perhaps, as due to a more rapid organization of the energy involved which is correlated with a quicker insight into the relationship of the terms. Whatever the particular phenomenological character of the configuration, however, those which are successfully organized for the task at hand possess a certain *bi-polarity* which insures the production of the correct response. It seems helpful to interpret the differences in the relative recall values of the categories as due to differences in the ease with which this *bi-polarity* is maintained or improved.

An examination of the phenomenological character of the configurations classified under the various categories reveals a difference in complexity. Two words are probably more adequate for the expression of opposition than for that of any other relation. It is doubtful whether one can think of an object and a part or attribute without imagining other parts or attributes. And the suggestion of causality by two words is construed in a rather elaborate imaginal setting. Since the tensions between the parts of an energy pattern tend to become equalized with a lapse of time, we would expect that, other factors being equal, the more complex a configuration the more difficult would be the maintenance of its *bi-polarity* and so the less surely would its reactivation lead to the correct response.

The difference between the configurations initiated by antonyms and synonyms is not so much that of complexity as of tension between the parts. Two synonyms such as "rapid–swift" refer to slightly different degrees of speed. Two antonyms such as "slow–fast", however, refer to opposite or extreme degrees of speed. The tension between the parts of the energy pattern is weak in the former case and strong in the latter. Hence, the *bi-polarity* of antonyms is more easily maintained at an effective level than that of synonyms.

It must be admitted that the whole-part configurations are somewhat anomalous in that they were retained better than antonyms in the major experiment. These configurations, however, are often organized by a combination of two types of relationship. In "barrel–hoop", for example, a hoop may be envisaged not only as a part of a barrel but also as serving an important function with reference to the whole. One would expect the *bi-polarity* to be more easily maintained in such cases.

Finally, if the relationship between the terms of an 'associate' is vaguely apprehended or if the subject is aware of having made a mistake in immediate recall, we may suppose that the configurations involved in such cases are subject to a process of growth or reorganization either above or below the conscious level which may make them effective at the time of the delayed recall. Apparently the effectiveness of these processes is also

positively correlated with the ease with which the *bi-polarity* of a configuration is maintained.

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AN EXPERIMENTAL STUDY OF RHYTHMS

by

BYRON C. SARVIS

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I. INTRODUCTION

The study of rhythms or periodicities in connection with continuous work has been a problem of considerable importance in the field of psychology for many years. To quote one author (1), "There is a periodicity about everything we do; heart action, breathing, eating, sleeping, and the like, occur rhythmically, under undisturbed conditions. Many individuals do their best intellectual work early in the morning, others prefer working late at night; each has his definite work rhythms. The fatigue curve ordinarily obtained in the ergograph experiments reveals rhythms of muscular contractions of higher and lower amplitudes. The knee jerk elicited at frequent, regular intervals over a prolonged period shows the same phenomenon. Workers in factories who make stereotyped movements for hours at a time show periodic fluctuations in their output."

The question naturally arose as to whether we should find rhythms in all motor performances of a certain type, and also in those performances which, while they were motor in nature, involved learning. Equally important are the questions: What are the factors which determine these rhythms? and Do such rhythms persist over a period of time?

The purpose of the present study was to discover whether simple motor performances showed rhythms. The original performance consisted in tracing blindfolded a simple maze which had no cul-de-sac, but which did have regular niches along the side of the groove through which the subject ran the stylus. Since this problem involved learning, an even more simple apparatus, a square tracing board having smooth grooves, was also used.

A rhythm may be described as a series of successive responses of approximately uniform pattern, each group of responses containing one or more phases of the larger rhythm. In the present study the repetition of similar patterns in the time curve of the particular performance was taken as evidence of the existence of a rhythm.

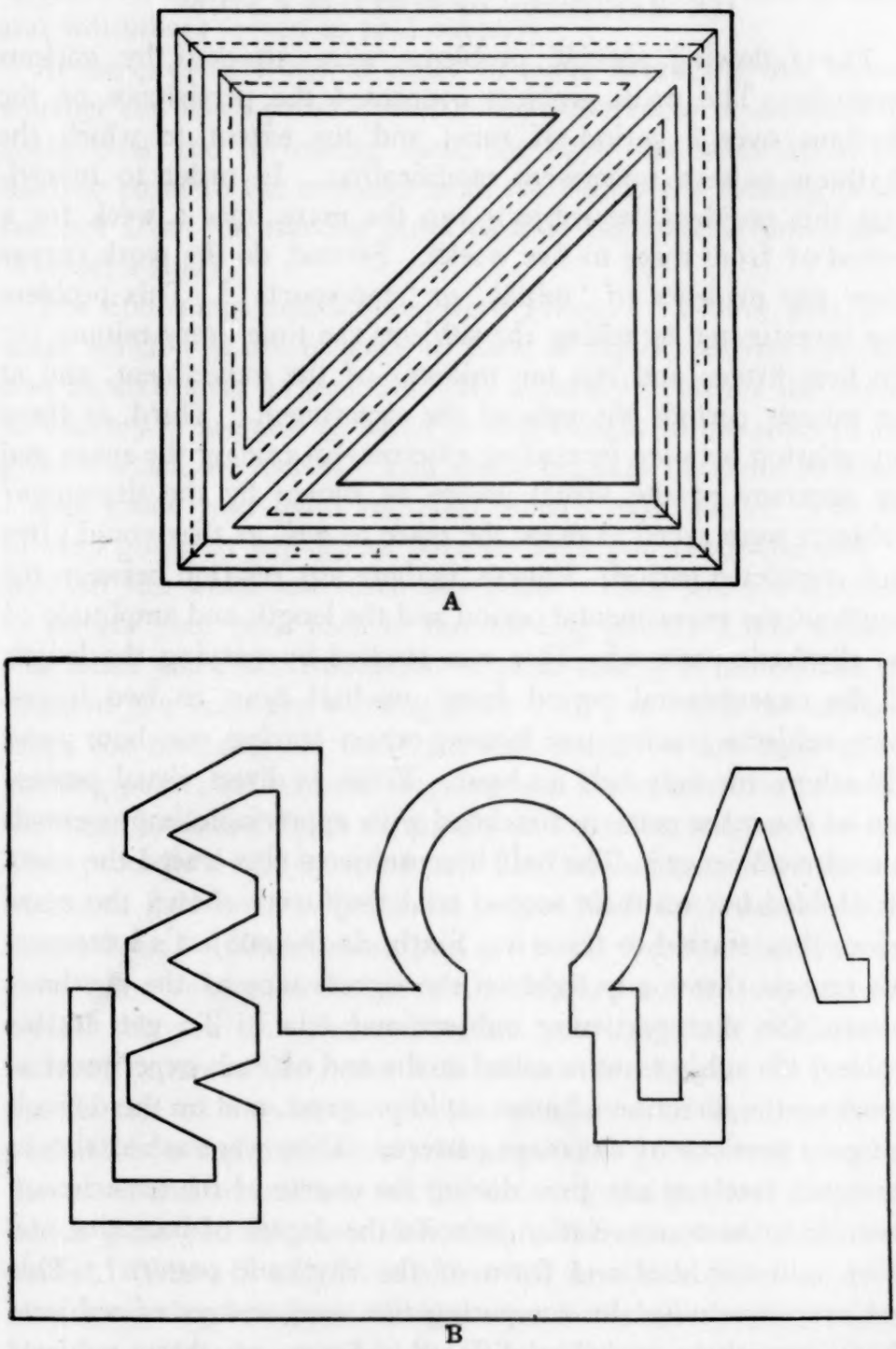
II. General Problems

1. Wheeler's Original Study. Wheeler began in 1923 at the University of Oregon a study of the periodicity of performance. His procedure consisted in having subjects trace a simple maze while blindfolded. The subjects were required to trace the maze as rapidly as possible for a period of two hours, no time being allowed for relaxation. The time curves showed striking periodicities of performance.

The study was later carried on at the University of Kansas from 1924 to 1931. The writer served as observer for Wheeler from 1927 to 1929, and from 1929 to 1931 pursued the problem independently under modified conditions.

The subjects were undergraduate students at the University of Oregon, and undergraduate and graduate students at the University of Kansas. Approximately thirty subjects were investigated at the University of Oregon and one hundred subjects at the University of Kansas.

The apparatus (Fig. 1) consisted of a brass maze with outside dimensions of nine and one-quarter inches by twelve and one-quarter inches. This maze contained no culs-de-sac but did have small niches cut in the grooves. A stylus and a pair of goggles were also provided for each subject.



A

B

FIG. 1. A. Diagram of Apparatus to Show Periodicity Without Learning.
B. Diagram of Maze to Show Periodicity With Learning.

III. Repetition of Wheeler's Study

The following specific problems were attacked by various methods. The main problem concerned the persistence of the rhythms over a period of time, and the extent to which the rhythmic pattern underwent modification. In order to investigate this problem the subjects ran the maze once a week for a period of from three to five weeks. Second, do the work curves show any evidence of 'initial' or 'end-spurts'? This problem was investigated by telling the subjects the time every minute for the first fifteen and last ten minutes of the experiment, and at ten minute periods throughout the experiment. Third, is there any relation between increasing efficiency in tracing the maze and the accuracy of the visual image as shown by the drawings? Subjects were asked to draw the maze as well as they could after each completed period. Fourth, is there any relation between the length of the experimental period and the length and amplitude of the rhythmic pattern? This was studied by varying the length of the experimental period from one-half hour to two hours, some subjects tracing two hours; others tracing one hour; and still others for only half an hour. Fifth, is direct visual perception of the maze pattern correlated with appreciable improvement in motor efficiency? The half hour subjects first traced the maze blindfolded but on their second trial they were shown the maze before they started to trace it. Sixth, do the subject's introspective reports throw any light on the significance of the rhythmic pattern for that particular subject and trial? To get at this problem the subjects were asked at the end of each experiment to report on the direction of most rapid progress, and on the difficult and easy portions of the maze pattern. They were asked also to introspect freely at any time during the course of the experiment. Seventh, is there any relation between the degree of incentive and effort, and the level and form of the rhythmic pattern? This problem was studied by comparing the work curves of subjects whose incentives probably differed. Some of these subjects offered their services out of friendship for the experimenter, others from the viewpoint of scientific interest, others to make

up absences in general psychology classes and to raise their grades, and still others served as paid subjects.

In the present study in order to avoid averaging and to see whether the maze pattern offered any differences in difficulty in going over and in coming back, the time was taken from the starting point to the end and from the end to the starting point, and not from the starting point back to the starting point as in Wheeler's study.

The following instructions were given: "Before you is a maze which you are to learn to trace as rapidly as you can, but also as accurately as you can. By accuracy is meant the extent to which you are able to avoid getting caught in the sides of the groove which are niched. You are to begin at the point to which I shall guide your hand and start when I say "Go". You are to keep going as rapidly as possible until you reach the end. I will tell you when you reach this point. Then you are instantly to retrace your path back to the starting point. I will also tell you when you reach this point. I shall take your time from the moment you leave the starting point until you reach the end and from the moment you leave the end until you are back at the starting point; but without stopping you are to continue to thread the maze back and forth as rapidly and as accurately as you can. This procedure will be continued for two hours. (For the one hour and half hour subjects the proper time was inserted in the instructions.) Nevertheless you are to do the best that you can every time you make the circuit. You are not to stop and rest until I tell you to. Remember that your object is efficiency in learning to trace the maze with all possible speed. It is not a mental test of any kind. At the conclusion of the experiment you will be asked to draw as well as possible your visual image of the maze and to indicate on the drawing the parts of the maze which gave you the most difficulty, and those parts which were easiest. You will also be asked to tell in which direction, going over or coming back, you think you made the most rapid progress. You are to introspect freely during the course of the experiment as to feelings of fatigue and rested periods, and as to any changes in the difficulty of the maze and in its pattern. At the end of the

final trial of the experiment you will be shown your results." (Fig. 1, B.)

IV. A Study of Periodicity Without Learning

Since the tracing of the maze mentioned above definitely involved learning, an even more simple apparatus was used: a square tracing board with outside dimensions two feet by two feet, which had smooth grooves and a diagonal up the center (Fig. 1, A). To prevent the subjects from losing the stylus and thus losing time in tracing as they had in the maze tracing, overhanging tracks and a special stylus were used. A pair of goggles was provided for each subject. The subjects were ten undergraduate students who performed the experiment once a week for a period of four weeks.

The following specific problems were investigated by various methods. First, do the work curves obtained from the square tracing board, in which learning is not involved, reveal rhythmic patterns? The regular repetition of similar patterns in the time curve was taken as evidence of the existence of rhythms. Second, do these rhythms persist over a period of time? To test this point the subjects were required to perform the experiment once a week for four weeks. Third, is there a relation between the subjects' introspective reports of feelings of fatigue and rested feelings, and motor efficiency at the time? Fourth, how does the general pattern of rhythms in non-learning performances compare with the pattern in performances which involve learning? Rhythms obtained in the repetition of Wheeler's study were compared with those obtained in the present study.

The following instructions were given: "Before you is a square tracing board (the subjects were shown the tracing board before the experiment began) which you are to trace as rapidly as you can. You will trace twice around the square and then once around the triangle formed by the diagonal and the two sides. You are to keep constantly repeating this procedure for half an hour. Remember your object is to trace the pattern as rapidly as possible. You are to report throughout the process of the experiment every time you feel fatigued and when you again

feel rested. You are also to introspect freely throughout the course of the experiment."

V. Experimental Results—Learning

Since the subject of rhythms in simple motor performances has been studied only recently there is no absolute technique as yet devised to demonstrate statistically the existence of these rhythms. In order to understand the results of this experiment it will be necessary for us to present the technique employed in the present study. The technique employed was that used by Wheeler (1) with certain modifications which seemed necessary during the course of the present study.

A careful study of the curves of work obtained in this experiment revealed several characteristics which give significance to these rhythmic patterns. One of these is *major slants* which are slopes from a high point to a low point, and from this low point to a new low point; another, *major curves* which are rhythmic patterns containing high points at both the beginning and the end or rhythms in which steeples concentrate in the center, giving a definite arch-effect to the curve, and showing relatively broad, clear spaces over the intermediate 'low' regions; or, rhythms showing characteristically 'spaced' or 'crowded' steeples throughout; or rhythms having repeated patterns of short and tall steeples characteristically an ascending or descending staircase of steeples; a third, *major resting places* which are places where the subjects seem to have reached a so-called 'plateau of performance', in which time for several trials was the same; a fourth, characteristic approaches to and departures from a low or high point such as openness or closedness of low regions of the curve, or high regions of the curve.

In examining the curves they were viewed as a whole. Isolated high and low points were not the only points of significance; instead, tendencies toward maxima and minima were emphasized. The major high points are very important for in many cases they are nine times the standard deviation.

In defense of this technique we offer the following: first, as yet no definite technique has been developed, hence we choose this

method as a working basis; second, the results obtained by using this method can hardly be attributed to chance since we find the same phenomenon in approximately all the one hundred and fifty or more subjects examined during the course of the experiment; third, the method is quite satisfactory in that it enables us to predict in most instances the high and low points of the subjects' forthcoming performance from a study of the first two or three rhythms. High points less than four times the standard deviation were ignored.

The ability adequately to see rhythms in a work curve comes only with prolonged experience in the analysis of curves configurationally. Frequently a single criterion is not sufficient to establish the point where a certain phase of the curve ends and another begins. More often four or five criteria are necessary. Occasionally it is obvious that at the place where one major phase ends and the next begins there is a minor phase covering from three to ten trials which could belong, on the basis of the criteria used, either to the preceding or succeeding phase. In numerous instances, if 'low points' on the curve are taken as the criteria the constancy of the rhythms is thrown off when, if the midpoint of the small, intermediate phase were chosen as the criterion, the successive rhythms would come out equal as to number of trials. In this study the practice was not followed of taking the average in such instances, but of selecting the most obvious of simpler criteria.

Frequently it happened that when the outstanding criterion of the rhythms was a series of high points, the low points were less orderly in their succession. Conversely, when low points were orderly in their succession the high points were frequently less regular. In some cases both the high and low points followed one another with mathematical regularity in the same curve.

VI. The Existence of Rhythms

We find that all the subjects in Wheeler's original study, 30 in number, show definite rhythms in their performances. Waves were found of approximately equal length and characteristic form. These rhythms, in the majority of cases, were so regular

that after examining two or three of them it was possible to predict the high and low points in the forthcoming trials with almost mathematical certainty. The rhythms tend to maintain the same length throughout the curve of learning for that particular sitting. There is only an occasional tendency to shorten and when the rhythmic pattern shortens it *does so by the amount of a phase of a minor rhythm;* not all the major rhythms change. Each major rhythm seemed to have the same number of minor rhythms except at such times when the rhythmic pattern tended to shorten by the extent of a phase of a minor rhythm as the learning process progressed. These minor rhythms in turn seemed to be broken up into smaller rhythmic patterns which may be called phases of the minor rhythm. Though these phases might differ from rhythm to rhythm they showed a fairly regular recurrence.

The work curve of a typical subject, 1, shows these rhythmic patterns very definitely (Fig. 2). The total number of completions of the maze pattern was 140.

The major slants are as follows: from trial 1 to trial 75 (75 trials) and from trial 75 to trial 140 (65 trials). We believe that if the subject had continued the experiment for a longer period we should have found at approximately trial 150 a point lower than the point at 140 and this would make the major slants 75 and 75. If we disregard the first ten trials when the subject was orienting himself to the problem we would get major slants of 65 and 65. Disregarding the first ten trials when the subject must be considered as orienting himself to the maze pattern we find *major high points* at 15, 48, (interval of 33) 80, (interval of 32) 110, (30) 127, (27). The *major low points* occur at 19, (19) 54, (35) 75, (21) 108, (38) and 136 (28).

On the basis of the major slants we may say that the subject has major rhythms of 75 and 65. The subject shows a progressive decrease in the frequency of major high points as the learning progresses. This is in line with the work of Bills (2) who found that in mental blocking practice tends to make the peaks occur less often. The major low points also show a decreasing frequency which may be due to stabilizing of the energy pattern. In the minor rhythms there is a regular alterna-

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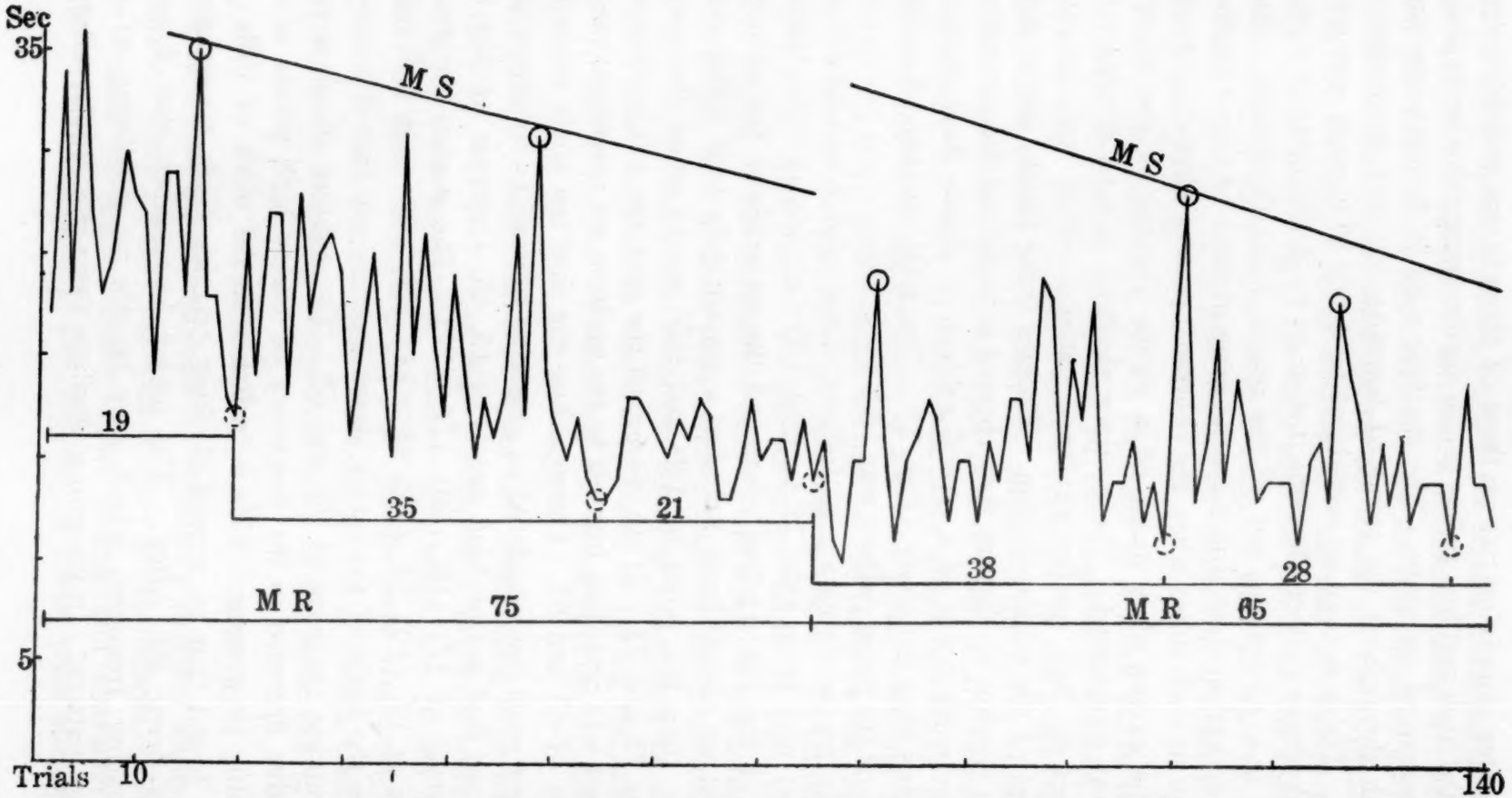

FIG. 2. Curve of Subject 1 During Continuous Practice Showing Major Slants (MS) and Major Rhythm (MR). Circles Indicate High Major Levels; Dotted Circles Indicate Major Low Levels.

tion of long and short patterns; short (19), long (35), short (21), long (38) and short (28). The minor rhythms all seem to have the same number of phases. Two phases appear in each though these phases differ in their extent.

In the work curve of subject 2 (each subject picked at random) we also find rhythmic patterns (Fig. 3). The total number of completions of the maze pattern was 130. Disregarding the first ten trials when the subject was becoming oriented to the maze pattern we find *major slants* from 10 to 58 (48), and from 58 to point 102 which is the low point before the major high point (44). The *major high points* seem to be at 13, 61, (48), 106 (45). *Major low points* appear at 58 (48 due to omission of the first ten trials) and 102 (44).

An interesting point in this curve is that the major low points and the major high points have almost the same frequency, and this frequency is almost exactly the same as the extent in trials of the major slants. The curve shows no definite minor rhythms but each major rhythm exhibits two phases. These phases differ, however, in the number of trials which they include.

All of the subjects in this part of the experiment, approximately 130, showed fairly definite rhythmic patterns. Each subject's curve revealed a pattern which was characteristic to himself alone.

In subject 3 major low points occurred at the following intervals expressed in number of trials, each low point marking the end of a major slant in the curve: 48, 40, 33, 30, 34. Major high points occur at the intervals 51, 41, 41, 41, 30, 31. The first major rhythm was approximately 10 trials longer than the succeeding ones in a surprising number of subjects. This may be interpreted to mean that the subject does not 'reach his stride' until a few trials are spent in becoming oriented to the maze. If 10 trials be arbitrarily taken off from the first major phase, note that there would have been 4 successive rhythms exactly 41 trials in length. Then the rhythm took on another number, approximately 30. Also, in a surprising number of cases, the size of reduction in the major rhythms, when such a reduction occurred, was the same as the number of so-called

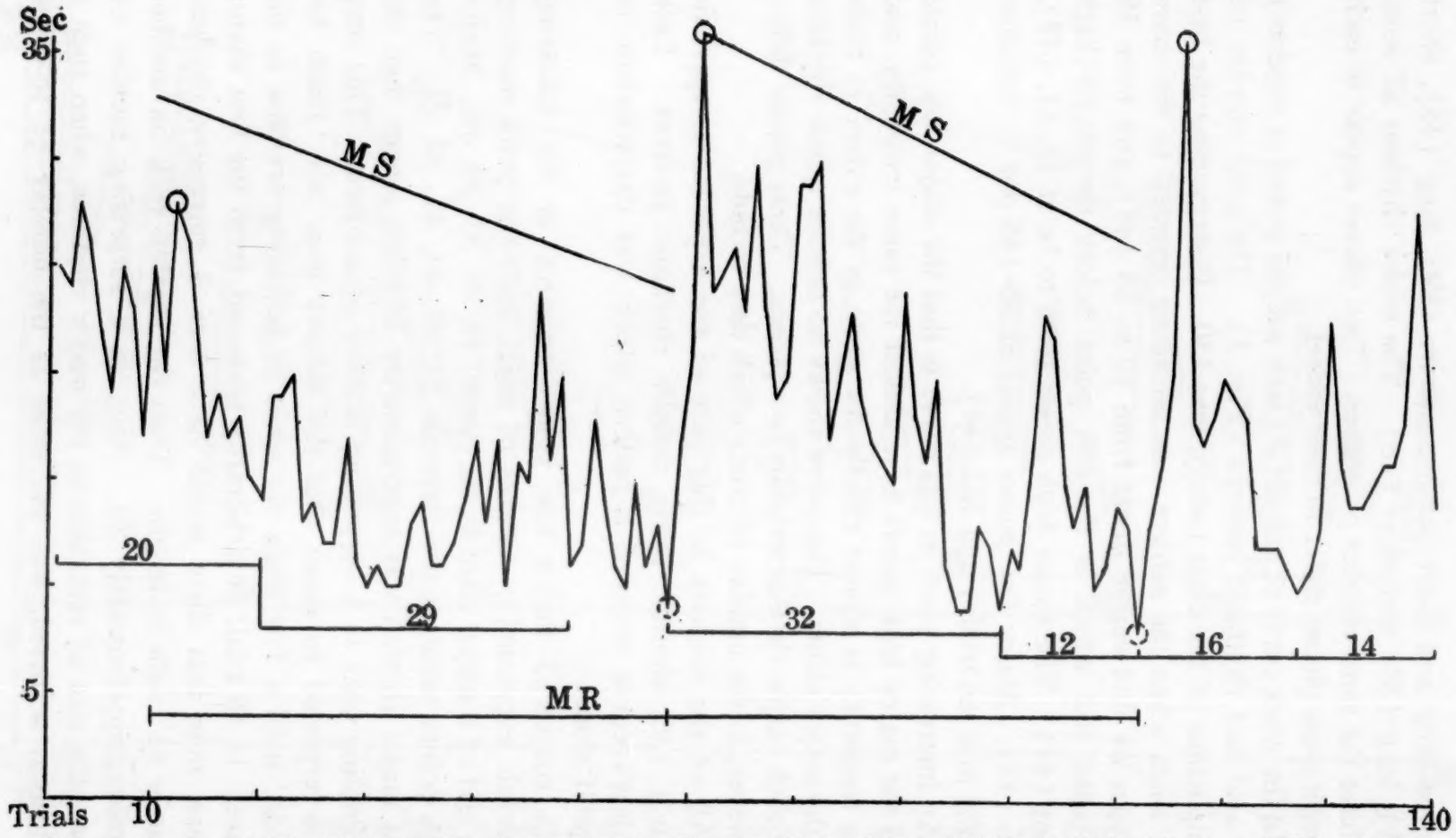

FIG. 3. Curve of Subject 2 During Continuous Practice Showing Major Slants (MS) and Major Rhythm (MR). Circles Indicate Major High Levels; Dotted Circles Indicate Major Low Levels.

'orientation trials'. In subject 4 the rhythms did not show major slants but were 'arched'. The major periods were 36 (trials), 36, 44 and 43. There were no major high points. In subject 5 the major rhythms had the periods 52 and 50; these revealed sharp minor rhythms of the following periods: 13, 14, 13, 12, 12, 13, 14, 11.

In subject 6 major slants and rhythms coincided in periods of 46 and 45 trials. Major high points occurred at the intervals 19, 31, 27, 31. Major low points occurred at the intervals, 46, 45 and 32. There is a tendency in all curves for the major high points to spread out and for the major low points to become closer together as the work curve progresses. The expansions and contractions of the rhythms are by the amounts of recurring minor rhythms. In subject 7 there appeared a definite alternation of long and short periods: 48, 16, 46, 18, 44, 22. Minor phases occurred as follows: 17, 15, 16, 16, 16, 19, 13, 18, 18, 14, 12. In subject 8 (a blind subject) the major periods were 31, 37, 36, 43, 32. This curve was different from any other in having less distinct high or low points, but in revealing 'arches' in the curve of uniform pattern throughout the 179 trials. In subject 9 the major periods were 52, 41, 42, 35, 38, 37. There was an unusually marked recurrent patterning of each phase. There were no outstanding high points. In subject 10 the major periods were 55, 32, 57, 16. It frequently happened that the reduction of a phase was by one-half of a previously occurring rhythm. Major high points occurred at the intervals 35, 40, 39, 44; low points at the intervals 38, 49, 30, 43. In subject 11 the major periods were 40, 30, 32, 26, 28. In subject 12 the major rhythms were 59 and 59; minor rhythms were 30, 29, 28 and 31. In subject 13 the major periods were 50 and 46; minor periods were 15, 17, 18, 20, 15, 11. Subject 14: 19, 36, 35. In this case the major slant extended only half the distance of the major rhythm; that is, the periods divided themselves into two definite halves each showing a striking pattern which repeated itself. The first half showed a descending 'staircase' of steeples; the second half was 'smooth' and 'open'.

Subject 15: major rhythms 47, 48, 48, 41, 47, 43. Minor

phases: 18, 14, 15, 15, 18, 14, 10, 12, 11, 15, 13, 12, 16, 16, 15, 16, 21, 22. Major high points: 74, 80, 82. Subject 16: 63, 58, 58, 49; minor periods: 11, 13, 9, 9, 10, 11, 9, 6, 11, 9, 6, 7, 10; 9, 9, 11, 11, 10, 9, 10, 9, 11, 9, 11. High points: 126, 109. Subject 17: 39, 38, 28, 37, 31, arranging themselves into 39, 66, and 68. High points: 43, 44, 49, 69 (33 and 36). Subject 18: major periods: 62, 50, 51, 24, 50, 43, 23, 23, dividing into 14, 25, 14; 13, 15, 13, 9; 10, 13, 17, 11; 12, 12; 14, 14, 10, 12; 12, 15, 16; 12, 11; 12, 11. Subject 19: major periods: 69, 71; minor periods: 36, 33; 25, 26, 20; sub-minor periods: 17, 19, 15, 18, 11, 14, 11, 15, 9, 11, in order. Subject 20: major rhythms: 47, 46, 51, 42, 50, 50. Subject 21: 44, 43.

VII. Persistence of the Rhythmic Pattern Over a Period of Time and Extent and Nature of the Modifications of the Pattern

The subjects in this part of the experiment ran the maze once a week from three to five weeks. The curves for each week were compared to see if the rhythmic pattern had persisted.

The work curves of subject 22 are described in detail. This subject was a senior member of the staff of the Department of Psychology and served as a subject because of a scientific interest in the problem. She performed the experiment for a two hour period once a week over a period of four weeks. The results follow.

First week. The total number of completions of the maze pattern was 329. The *major slants* appear to be around 90 trials in length. Disregarding the first ten trials when the subject was orienting herself to the problem we get the major slants from 10 to 90 (80), 90 to 185 (95), and from 185 to 275 (90). *Major high points* appear at 87 (87), 185 (95), and 275 (90). The curve shows *no major low points.* The major rhythms appear to be from 10 to 90 (80), 90 to 177 (87), and from 177 to 272 (95). The subject shows a progressive lengthening in the extent of the rhythmic pattern.

These major rhythms appear to break up into the following minor rhythms: 40 (30), 65 (25), 90 (25), 116 (26),

145 (29), 177 (32), 211 (34), 244 (33), 272 (28), 302 (30), and 302 to X (end). Each major rhythm has the same number of minor rhythms, namely three. The last two minor rhythms, those of 30 and X, are probably minor rhythms of the next major rhythm.

Second week. The total number of completions of the maze pattern was 800. The work curve is relatively stable in amplitude and exhibits no major slants. Except at points 120 and 724 we find no points which appear to differ significantly from the standard deviation. These two points are isolated high points which rise suddenly in one trial and drop just as suddenly. They differ from major high points which are attained gradually and from which the drop is also gradual. The curve shows no major low points. We do find in the curve certain points which, though quite low, show a tendency toward maxima so far as the rest of the curve is concerned. These points give us the following major rhythms: 44 (44), 120 (75), 201 (81), 271 (70), 315 (44), 393 (78), 472 (79), 538 (66), 594 (56), 654 (60), 723 (69), and 788 (65). The general pattern appears to be a short rhythm followed by three longer rhythms and then another short rhythm followed by three more long rhythms. Toward the end of the curve we find the major rhythms being broken into minor rhythms. We find that the rhythm between points 538 and 594 (56) is broken into rhythms of 34 and 22. Between points 654 and 723 (69) we find two minor rhythms, 34 and 35. Between points 723 and 788 (65) we find four minor rhythms 19, 20, 15, and 11.

Third week. The total number of completions of the maze pattern was 883. The curve exhibits no major slants, no major high points, no major low points, and the major rhythms have disappeared or at least cannot be detected by the present technique.

Certain tendencies toward maxima (high regions) are observable in sections of the curve where the subject seems to have lost the pattern which had previously kept the curve of performance at a fairly constant level. This may be related to the work of Snoddy who found that series practice, such as the subject was following in the present experiment, gave rise to an irradiation

pattern probably caused by the simultaneous functioning of opposed musculature.

The tendencies toward maxima appear in the following places on the curve: from point 305 to 325 (20), 409 to 425 (16), 597 to 607 (10), 674 to 680 (6), 735 to 754 (19), 761 to 769 (8), and 891 to 897 (6). These tendencies seemed to come at fairly regular intervals and in a definite order. We find a group of four which become progressively shorter in extent and then a group of three which also becomes progressively shorter.

Fourth week. The curve shows no major slants, major high points, major low points and major rhythms. The subject seems to have attained a pattern which will give the maximum efficiency for the length of the experimental period. We find at this time large major ' rest periods ' in which the subject ran a number of trials in exactly the same length of time.

Number 22 was a superior subject, as regards speed, a factor involved in the early disappearance of the rhythmic pattern, for as Bills (2) has shown in his work on blocking, the fastest individuals have fewer and shorter blocks than the slow individuals. In the present study it appeared that the faster individuals showed fewer major high or major low points than the slow individuals and their rhythmic patterns were longer and tended to disappear sooner. This is but another way of saying that the fast individuals were less variable in their performance than the slow.

The work curves of subject 23 show very definite rhythmic patterns which persist over a considerable period of time. This subject was an undergraduate student. She traced the maze for a period of one hour once a week over period of five weeks. The results follow.

First week. The total number of completions of the maze pattern was 63. *Major slants* are not noticeable in this curve. One *major high point* is noted at 43. The curve shows no *major low points* but does show throughout a general tendency toward a lower level. *Major rhythms* in this trial, as judged in terms of the tendency towards significant low points, appear to be 25 and 26. There seems to be a progressive series of *minor rhythms* in this day's work. In terms of *low points* we find these rhythms as

follows: 9, 15 (6), 22 (7), 30 (8), 39 (9), 49 (10), and at 60 (11).

Second week. The total number of completions of the maze pattern was 258. No exact *major slants* are observable in this curve though there is a general tendency downward until about the middle of the curve. Two very significant *high points* appear, the first at point 130 and the second at point 251 (121), which almost divide the curve in half. There are no *major low points,* but a general tendency toward low levels on the curve. There are fairly definite *major rhythms* as follows: 8 to 30 (22), 54 (24), 84 (30), 110 (26), 136 (26), 166 (30), 188 (22), 218 (30), 242 (24). These major rhythms exhibit smaller rhythmic patterns within themselves as follows: 22 (7, 9, and 6), 24 (6, 10, and 8), 30 (10, 8, and 12), 26 (4, 8, 6, and 8), 26 (10, 8, and 8), 30 (8, 7, 9, and 6), 22 (6, 6, and 10), 30 (12, 10, and 8) and 24 (10, 8, and 6).

Third week. The total number of completions of the maze pattern was 345. This curve shows very definite *major slants:* the first is from 1 to 101 (101), the second from 101 to 200 (99), the third from 200 to 301 (101). The *major high points* are not so significant in this curve. They keep decreasing in size in accordance with their position in the major slant and their appearance is not as regular as in the preceding trials. They occur at the following points: 20 (20), 51 (31), 70 (19), 103 (33), 140 (37), 152 (12), 178 (26), 20 (22), 248 (48), 282 (34), 306 (23), 320 (15), and 340 (20). There are no especially significant *major low points* in this curve. The *major rhythms* are the same as major slants, that is 101, 99, and 101. Certain definite *minor rhythms* appear in this curve at the following points: 4 to 33 (29), 59 (26), 84 (23), 103 (19), 130 (27), 159 (29), 180 (21), 203 (23), 226 (23), 250 (24), 272 (22), 298 (26), and 327 (29). These minor rhythms are divided into the following number of *phases:* 3, 2, 2, 2, 3, 3, 3, 2, 3, 3, 3, 3, 3, and 2.

Fourth week. The curve for the *fourth week* shows *no major slants.* The *major* high points, while not particularly great in amplitude, do tend to mark the curve off rather sharply. They

occur at the following points: 56 (56), 124 (68), 205 (81), 258 (53), 322 (64), and 387 (65). No *major low points* appear. The major rhythms are as follows: from 1 to 55 (55), 55 to 123 (68), 123 to 204 (81), 204 to 254 (50), 254 to 321 (67), and from 321 to 389 (68).

Fifth week. The work curve for the *fifth week* shows a further modification in the rhythmic pattern. The total number of completions of the maze pattern by the subject in this particular curve was 463. No *major slants* are apparent in the curve of work. With the exception of trials 213 to 235 the curve shows no significant *major high points.* These trials, however, are quite important for they clearly indicate a loss of the pattern on the part of the subject. This loss of pattern which indicates the onset of an irradiation pattern seems to divide the total number of completions almost in half. The *major rhythms* appear to be from 1 to 59 (59), 59 to 126 (67), 126 to 210 (84). Here the subject shows the loss of the pattern. The next major rhythm is from 235 to 320 (85), and finally from 320 to 400 (80). The work did not extend long enough for us to get the next major rhythm after the four hundredth trial. This curve marks the first appearance of the *major rest periods.*

Subject 24, first week, one hour sitting. Major rhythms as determined by major slants: 76, 81, 80, dividing into minor rhythms of 30, 21, 25; 31, 24, 26, 43 and 37. The last two divided into 13, 13, 17; 12, 13, 12. Second week: major slants at the definite intervals of 105, 101, 101, dividing into 25, 24, 22, 24, 10; 23, 22, 24, 21, 11. Minor rhythms then become lost. Third week: major slants, 106, 159, 146. Note the following low points: 21, 33, 32, 29, 20, 29, 24, 22, 20, 20, 25, 30, 23, 20, 19, 20, 29, 28, 22, 21, 17, X (unfinished). All but two of these intervals cluster about the numbers 20 and 30. Fourth week: high points at intervals 171 and 199. Rhythms obscured in evenness of the curve. This subject came back for a fifth time. The distribution of major 'resting places' is interesting. During the third week there were 16 of three trials in length, 5 of four, 8 of five, 2 of six, 1 of seven and 1 of eight. The long resting placed occurred at approximately equal intervals and tended to

cluster together. During the work period of the fourth week, 'resting places' were distributed as follows: 19 of three; 20 of four; 1 of five; 4 of six; 1 of eight; again an orderly distribution. But now note the distribution of the fifth week: 28 of three; 7 of four; 16 of five; 1 of six; 2 of seven; 6 of eight; 1 of twelve; 1 of sixteen. It is believed that the modes at 3 (number of trials per resting place) 5 and 8 are significant for the fact that 3 and 5 total to 8! Why this should occur is a mystery at present, but it repeats itself in several of the one-hour, four-week subjects. For example, distribution of the resting places in subject 25, the fourth week, shows modes at numbers per period 3, 4, and 7! Numbers 5 and 6 are skipped; then there is another clustering of rest-place lengths around 11.

Subject 22, like subjects 24 and 25, revealed another interesting phenomenon in relation to the distribution of 'rest places'. In her fourth week the distribution is as follows: 41 of three; 23 of four; 13 of five; 21 of six; 2 of seven; eight is skipped; 4 of nine and 3 of ten; eleven, twelve, thirteen and fourteen are skipped; 1 at fifteen; 1 at nineteen. Note that as the rest places increase in length the distribution of modes tends to scatter up the range, skipping numbers in some sort of geometrical progression! All subjects of this group showed a similar tendency. This tendency reveals itself at first in the distributions of the third week of practice, but becomes sharper as practice continues. Thus the 'resting places' show signs of definite orderliness in their occurrence.

The curves for the subjects who traced the maze for half an hour exhibit, on the first day, rhythms about the same as the one and two hour subjects, though the pattern is considerably lower in amplitude and longer in extent. On the succeeding days the curves showed an absence of major high points, major slants and major low points. The subjects seemed to strike their level of maximum efficiency almost immediately as is shown by the early appearance of major rest periods.

All, with the possible exception of the half hour subjects, showed evidence of the existence of rhythms in their work curves. These rhythms persisted over a considerable period of time. The

general level of the curve may fall, but the form remains relatively constant. With the passing of time the major high points dropped; the major rhythms spread out as though the curve had been flattened. The major low points tended to disappear as the learning continued. As the learning process continued, *major rest periods* began to appear. These may be periods in which the state of muscle co-ordination and nervous impulses are best balanced. These rest periods continued to grow larger until the rhythms seemed to disappear and the time curve became a relatively straight line.

VIII. A Study of Periodicity Without Learning—Results

Do the Work Curves Obtained from the Square Tracing Board Reveal Rhythmic Patterns? Since the method employed by Wheeler in his original study and by the author in the earlier part of this experiment seemed to involve some degree of learning we wished to ascertain to what extent the rhythmic patterns obtained in those experiments were the result of the learning involved. The simple square tracing board described earlier was used in this experiment to test this factor.

The curves of subject 26 show rhythmic patterns much like those from the first maze. The first week the total number of completions of the maze pattern was 375. The curve showed no *major slants*. The *major high points* were 54 (54), 104 (50), 159 (55), 206 (47), 258 (52), and 315 (57). The *major low points* were at 123 (123), 242 (119), and 351 (109). Since the major low points are not as regular as the major high points we have judged the rhythms in this part of the experiment largely in terms of the pattern from high to high points. The *major rhythms* in this curve appear to be of the same extent as the major high points, that is 54, 50, 55, 47, 52, and 57. Certain definite *minor rhythms* stand out very clearly in this curve. They occur regularly and have about the same extent until toward the middle of the curve where the longer minor rhythms tend to break down into smaller ones. We can, however, break up these larger minor rhythms which we found in the first part of the experiment into

two smaller rhythms which have almost the same extent as the small minor rhythms which we find after the middle part of the curve has been reached. These minor rhythms appear at the following points: 26 (26), 52 (26), 79 (27), 102 (23), 123 (21), 145 (22), 172 (27), 185 (13), 198 (13), 210 (12), 226 (16), 242 (16), 254 (12), 269 (15), 282 (13), 298 (16), 312 (14), 326 (12), 344 (18), 360 (14), and 374 (14). The larger minor rhythms of 26, 26, 27, 23, 21, 22, and 27 break up into the following smaller minor rhythms: (11, 15), (13, 13), (14, 13), (13, 10), (10, 11), (11, 11), and (14, 13).

The curve for the second week also shows definite rhythmic patterns. The total number of completions of the maze pattern is 515. The *major high points* are as follows: 140 (140), 261 (121), and 396 (135). The curve shows no *major slants.* The *major low points* seem to be covered up by the increase in the efficiency in the maze tracing; all the low points tend toward a common base-line. The *major rhythms* appear to have the same extent as the major high points, that is 140, 121, and 135. The curve shows very definite *minor rhythms* whose extent is shown by the following points: 45 (45), 80 (35), 114 (34), 140 (26), 175 (35), 195 (20), 215 (20), 233 (18), 247 (14), 261 (14), 312 (51), 369 (57), 438 (69), and 473 (35). On the last part of the curve we find the smaller rhythms changing into the larger rhythms which are about equal to two of the smaller rhythms.

The curve for the third week is of somewhat doubtful value since the subject broke the apparatus at trial 155. The curve shows no *major slants.* The *major high point* falls on the eighty-fifth trial. No *major low points* appear in the curve. The *major rhythm* as judged from high point to high point appears to fall on trial 85. Certain definite *minor rhythms* appear despite the fact that the apparatus broke down. The minor rhythms fell on the following points: 27 (27), 53 (26), 80 (27), 101 (21), 122 (21), and 145 (23). Each major rhythm seemed to have three minor rhythms (27, 26, 27) and (21, 21, 23). The curve tends to flatten out. We find the appearance of major rest periods.

In the curve for the fourth week we note the absence of *major slants, major low points,* and, also, we are unable to point out either *major* or *minor rhythms.* We do notice some variability in the work curve and find certain *major high points* at the following trials, 82, 190, and 348.

While the curve of subject 27 shows no *major slants, major high points,* or *major low points* it still exhibits definite *major* and *minor rhythms.* The major rhythms fall on the following points: 50 (50), 100 (50), 143 (43), and 185 (42). The first major rhythm of 50 contains the following minor rhythms: 9, 9, 9, 9. The second major rhythm contains the following minor rhythms: 10, 9, 10, 10, 11. The third major rhythm contains the following minor rhythms: 10, 11, 10, 9, 5. The fourth major rhythm is composed of the following minor rhythms: 8, 9, 8, 9, 8.

There is evidence, therefore, for the existence of rhythmic patterns in simple motor performances that do not involve learning in the ordinary sense of the term. The rhythmic pattern is, however, less complex, lower in amplitude, and greater in extent. The pattern is more subject to modification over a period of time than are the rhythmic patterns which we obtain in the performances which involve more learning. Several things distinguish these curves from the curves in the more complex experiment: first, the major high and low points are not as frequent nor as significant as in the other type of problem. Second, major slants seem to be absent from these curves. Third, the rhythmic pattern disappears more quickly than in those curves of performance which involve learning. Fourth, we find early appearance of major rest periods.

IX. Summary and Interpretations

Space in this paper has been confined largely to a presentation of one phase of the study, namely, the existence and persistence of rhythms in work and learning curves. Several of the conclusions that follow are inserted for completeness and will be discussed at greater length in a subsequent paper.

1. The curves of all subjects (170) showed major rhythms of

approximately equal length throughout the curve for each period of work. Major rhythms shortened usually by the amount of a minor rhythm.

2. Rhythms persisted over a considerable period of time. The general level of the curve may fall, but the form of the curve remains relatively constant. As time went on, the major high points dropped; the major rhythms spread out as though the curve had been flattened. The major low points tended to disappear as learning increased. As the learning process progressed there appeared major rest periods. These may be periods in which the state of muscle co-ordination and nervous impulses were best balanced. These rest periods continued to grow larger until the rhythms seemed to disappear and the time curve approached a straight line.

3. The curves show no consistent evidences of 'initial' or 'end-spurts', or of 'warming-up periods'.

4. There is no relationship between increasing efficiency in tracing the maze and accuracy of the visual image as shown by the drawings.

5. The subjects' introspective reports throw no light on the cause of the rhythmic pattern.

6. Evidence points to the existence of rhythmic patterns in performances which do not involve learning as well as in performances which do involve learning. The rhythmic patterns in the non-learning performances are less complex, have fewer phases and are more spread out than in performances which involve learning. The rhythms disappear more quickly in non-learning performances than in those which involve learning.

7. The degree of incentive and the degree of effort have no appreciable effect on the level of the curve of performance for a particular problem. That is, a rhythm cannot be appreciably altered by voluntary effort, if the subject is co-operating in the experiment.

8. An explanation of these rhythms probably involves the following factors: *the complexity of the task,* for the more complex the task the more complex the rhythms and the greater their amplitude and extent; the *amount of organism involved,* for the

complexity of the rhythmic pattern seems to vary directly with the amount of the organism involved; the *degree of differentiation of the subject's behavior-patterns,* for the lower animals present little periodicity of work curves until their behavior becomes relatively differentiated (Richter). Physiologically, periodicity may be associated with *variations in the general relationship between energy-building and energy-spending* involving, *(1)* metabolic activity, *(2)* sex and other ductless glands, *(3)* functioning of the autonomic nervous system. In other words they are subject to daily variations about a moving 'axis' which in turn has a cyclical periodicity.

The following general theory is suggested, with acknowledgments to several investigators, especially Richter (9), Allen (6, 7), Hersey (8), and Wheeler (1). Until the organism becomes relatively differentiated we find little or no evidence of rhythms. When, however, the neuro-muscular system becomes differentiated, we find rhythms which seem to be influenced by the gross oscillatory aspects of nerve conduction. There are both enhancing and inhibitory phases of nerve impulses. When the inhibitory predominates, stimulation may produce stationary or even diminished results. When this phase is followed by the enhancing phase, further stimulation again becomes effective in raising the level of the curve of performance. The 'breathing places' on the work curve are due to inhibitory phases of more rapid neural oscillations of short duration, and the plateaus of major rest periods to those of long period oscillations.

The completed performance is the unit. The performance is directed in part by a goal which functions in the control of the behavior-pattern. The organism compensates for a large expenditure of energy by relaxing. This tends to keep a certain balance or level of metabolic activity in the attainment of the goal, tending to preserve the pattern until the goal is reached. It takes a long time to reach the goal and the level of the curve rises and falls. Time is subordinate to the goal, and the performance is on the 'all-or-none' principle as far as output is concerned.

There is much more orderliness about an ordinary work curve than is obvious at first glance. The problem is: How to tease it

out. The present study aims only to offer a few suggestions. It is evident from several years of intensive study of curves that much valuable information is lost by averaging them, and also by an unwillingness to study the patterns of the curve, seriously, with a group of criteria rather than one criterion in mind. Considerable skepticism has been encountered, informally, in regard to the whole matter of periodicity in the work and learning curve. This is unwarranted. One has to learn to see rhythms as one has to learn to detect the criteria of a good piece of lumber, or to test tea, tobacco and wine! It is as easy to err on the side of conservatism as on the side of radicalism, even in science.

Moreover, it should be remembered that in too complicated a task periodicities overlap each other to such an extent that they are obscured; in too simple a task fluctuations in the curve will inevitably be erratic. In a simple task, periodicities can be brought out by the mere expedient of increasing the amount of work done by the muscle, either by pressing the subject for speed or by making the muscle work against greater friction or a weight of some kind. In addition, the pattern of the required performance is an important factor. Within the limits of the complexity determined by the method, a stereotyped movement-pattern will be less rhythmic than one in which its minor movements are more highly differentiated and unlike each other.

The present investigation of rhythms throws light on certain studies made in the field of psychology from other viewpoints. Hartman (3) attempted to find the reliability of initial performance as a basis for predicting ultimate achievement. Using the method first suggested by Bair (4) to measure the speed of verbalization he obtained the following results. Correlation of the means of the first three and last three trials of each record gave coefficients of moderate size. The constancy of the values seemed to justify the assertion that the size of the initial score provided a reasonably good prediction of the final score, at least within the limits of the experiment. It was not known whether the situation would be altered with an extension of the trials. In the light of the present study it would seem quite important that the rhythm of the subject should be investigated as a whole,

for if the first three trials selected were at a point where there was a tendency toward maxima and the last three when there was a tendency toward minima there would be a very poor correlation. Our study seems to show, however, that if we have the first two rhythms of the subject we can predict the general pattern of his forthcoming responses.

Lennes and Fee (5) set out to find how nearly uniform in their performances are the most consistent performers and how greatly do the most inconsistent vary in this respect. Their study was purely statistical and gave them little knowledge as to the factors which influenced the variability at the time. In the present study it has been shown that not only the external stimulus-pattern influences variability but also the internal stimulus-pattern, and the goal which is functioning at the time. Certain results from the present study also tend to show that there is a direct relation between time and variability in that the length of the experimental period influences greatly the pattern of the response.

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THE MATURATION OF THE COLLEGE STUDENT AS EVIDENCED BY RETESTS WITH THE NATIONAL COUNCIL TESTS[1]

by

ONIAS BARBER BALDWIN

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I. INTRODUCTION

For a number of years a psychological examination has been the first step in the process of matriculation into the University of Kansas. Since the fall of 1925 the University has used the forms prepared by the American Council of Education. Records exist of approximately fifteen hundred scores in each of the forms of 1924, 1925, 1926, 1927, and 1928. During the scholastic year 1927–8, as a part of the laboratory procedure of the classes in psychology, seventy individuals were retested. The variation of the retest scores was so extreme it seemed worthwhile to enter into a more extensive retesting program. This paper reports the major portions of a study that was made under such a project.

[1] Submitted to the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

We have the initial tests and retests with the following time intervals between the two tests:

113	students	with	an	interval	of	19 hours
119	"	"	"	"	"	4 weeks
47	"	"	"	"	"	1 semester
249	"	"	"	"	"	1 year
115	"	"	"	"	"	1 year and 1 semester
117	"	"	"	"	"	2 years
20	"	"	"	"	"	2 years and 1 semester
130	"	"	"	"	"	3 years

II. Rendering the Scores Comparable

The scores of the initial tests and the retests of the data compiled are distributed among the six forms of the American Council Tests, 1924, 1925, 1926, 1927, 1928, and 1929. These tests have been undergoing, during the past years, a period of experimentation; consequently the raw scores are not comparable. The 1924 edition consisted of nine subtests, viz., Completion, Arithmetical Reasoning, Artificial Language, Proverbs, Reading, Opposites, Grammar, Estimating, and Reasoning. The time allowed for taking the test was one hundred twenty-five minutes. The 1925 edition consisted of the following subtests: Completion, Arithmetic, Artificial Language, Analogies I, Analogies II, Number Completion, Absurdities, and Opposites. The time allowed for taking the test was one hundred two minutes. The 1926 edition consisted of seven subtests: Opposites, Proverbs, Arithmetic, Artificial Language, Number Completion, Completion, and Analogies. The time allowance was sixty minutes.

The 1928 and 1929 editions consisted of five tests of the same type as the 1927 edition. The same time allowance, sixty minutes, was made. There were, however, modifications in the time allowance for individual subtests and some modifications of scoring.

When we approach the problem of making these scores comparable we find two procedures which are, after all, but different presentations of the same data. These are the "Variability Scale", in which each raw score is stated in terms of its standard deviation, and the "Percentile Scale". Otis (1) has pointed out the following correspondence of the two scales:

Mean	plus	3½	sigma	equals	99.98	in	percentile	rank
"	"	3	"	"	99.87	"	"	"
"	"	2½	"	"	99.4	"	"	"
"	"	2	"	"	97.7	"	"	"
"	"	1½	"	"	93.	"	"	"
"	"	1	"	"	84.	"	"	"
"	"	½	"	"	69.	"	"	"
			Mean	"	50.	"	"	"
Mean	minus	½	sigma	equals	31.	"	"	"
"	"	1	"	"	16.	"	"	"
"	"	1½	"	"	7.	"	"	"
"	"	2	"	"	2.3	"	"	"
"	"	2½	"	"	.6	"	"	"
"	"	3	"	"	.13	"	"	"
"	"	3½	"	"	.02	"	"	"

This correspondence has been utilized by McCall (2) in his *T* Score technique and in the construction of his tables. He has turned percentile ranks into *T* scores. His *T* Scale extends from minus five sigma to plus five sigma. A '*T*' is one-tenth of a sigma; hence there are one hundred *T* between his upper and lower limits. In actual practice, *T* scores usually range from fifteen to ninety. The gross scores of the 1927 form (16,554 cases) as reported by Dr. Thurstone in the *Educational Record* for April, 1928, consolidate into *T* Scale units ranging from fifteen to ninety. The gross scores of the 1926 form, based upon 5,137 individuals as reported in the *Educational Record* for April, 1927, consolidate into a range from 18.5 to 85.5. The 1928 scores, based upon the records of 30,653 students as reported in the *Educational Record* for April, 1929, consolidate into *T* scores with a range of 14.5 to 89. The 1929 form, based upon the scores of 7,640 individuals reported from a similar source, consolidate into a range of 13.5 to 84.

A common criticism of investigations based largely upon the statistical procedure has been that the refinement of statistical technique has developed altogether out of proportion to the crudities of the original measurements. Because of the numerous possibilities for error, both in the original and in the retests, it was thought that the comparisons would have more significance if the raw scores could be converted into units which, while statistically adequate, would be as *gross a unit as possible.* Accordingly the gross scores, as reported in the *Educational Record* for the forms of 1926, 1927, 1928, and 1929, were con-

verted by the McCall technique into standard deviation or *T* Scores. Because McCall, in his definition of a *T* Score, has based his scales upon the twelve year mean, and in order to avoid any ambiguity, it has seemed proper to call the units thus obtained in this study, the *Tc* scores, which means the *T* Score of the college population.

The problem of standardizing the scores for the 1924 and 1925 forms was complicated by the fact that Dr. Thurstone's reports in the *Educational Record* had not included a gross score. It was necessary to reduce each of the subtests to *Tc* scores. The scores made by the individual, in each of the subtests, were transformed to *Tc* scores and the means of these subtests were computed to constitute his total *Tc* score. The question immediately arose as to the necessity of using the entire nine subtests of the 1924 form and all of the eight tests of the 1925 form. All of the forms, from the 1924 to the 1928, have four tests in common: Artificial Language, Arithmetic, Completion, and Opposites. After some empirical comparison of the means of various combinations with the gross scores, the four subtests, common to all forms, were chosen with the addition of the Proverbs test for the 1924, and the Geometric Analogies for the 1925 form. The statistical procedure by which these *Tc* scores and all the data of this study were ascertained are available in the Library of the University of Kansas.

III. Analysis of Initial Scores of the 1928 Group

It seems obvious that any study of the maturation of the college student should be preceded by a careful analysis of the group at the time of the initial examination. In accordance with this logic, the studies of this section were undertaken.

The September examinations of 1928 were taken by one thousand four hundred thirty-one individuals. An examination of these data reveals the following facts:

Total number	1431
Tc Range	20–80 *Tc*
Median *Tc*	50.5
Age Range	15–35 years
Median Age	19 years
r of age and *Tc* scores	—.04

Of these one thousand four hundred thirty-one individuals, eight hundred seventy-five (875) were Freshmen:

Age range	15–35 years
Median age	18 years
Tc range	21–80 *Tc*
Median *Tc*	46.5
r of age and *Tc* scores	—.07
r of age (18–22 yrs.) and *Tc*	—.199

The mean scores tabulated by ages:

Age	Frequency	Mean Score
15	2	69
16	16	50.59
17	142	51.34
18	290	48.12
19	204	46.19
20	95	45.64
21	66	45.98
22	30	45.81
23	11	49.18
24	7	58.42
25	3	49.16
26	1	29.5
27	3	42.
28	2	51.5
29	0	
30	3	59.6

The distribution exhibits very nicely the factor of selection. The curve declining to age nineteen and its gradual ascent to the age of twenty-five indicates that those who have completed their college preparatory work before the conventional age of eighteen are more alert than those who have not been able to break the "lock step of education" and have arrived at the University, as a matter of administrative routine, at the age of eighteen or nineteen. The ascending curve from nineteen to twenty-five indicates that a higher degree of intelligence is required each year to break the inertia of existence and get students back into school after a period of absence.

It is the custom at the University of Kansas to classify all the examinees, irrespective of their college standing, into deciles which are based upon the total score. Decile rating indicates for the Freshman, then, not his comparative place among his classmates, but his place in a more or less heterogeneous group of which approximately eight hundred are Freshmen and six hundred are students advanced from Freshman standing. For the

purpose of a more detailed study, fifty Freshmen were selected by chance from each of the ten deciles. This original group of five hundred shrunk, through several processes of attenuation, to an ultimate four hundred thirty-five. The academic histories of these four hundred thirty-five were carefully studied to ascertain whether or not any of the factors of their college preparation might show a relation to their *Tc* scores.

It is at least thinkable that the type of work selected during the high school years may have had its influence upon the mental alertness of the various individuals. Scattergrams were accordingly worked out showing the relation of *Tc* scores to the number of units taken in Science, English, History, Vocational subjects, Mathematics, and Foreign Language. The following correlations were obtained:

r of Science units and *Tc* scores	.037
r of English " " " "	.030
r of History " " " "	—.156
r of Vocation " " " "	—.151
r of Math. " " " "	.268
r of Foreign Language " " " "	.329

Scores which would have any significance are those of History and Vocation, which show a small negative relationship, and Language and Mathematics, with .329 and .268 as their respective correlations. Even if the negative correlation were larger in regard to History, at least, there could be no doubt as to the causal relationship. He would be a hardy soul, indeed, who would venture to assert that the study of History makes boys and girls stupid!

It is fairly obvious that, in the competition for students existing between departments, the narrative element of History together with the lack of intricate detail in many of the History courses, make them attractive to students of low mental caliber.

The largest correlation is that of Foreign Language. Here the absence of any causal nexus is not so obvious. The tests themselves are strongly tinged with the linguistic flavor. The Artificial Language test, the Completion test, the Opposites test are to a large degree measures of types of language facility. It requires no great effort of one's credulity to believe that language

training, attention to sentence structure, choice of synonyms in translation, subtle grammatical distinctions would tend to develop these functions employed in solving these tests. The language handicap has long been recognized as an appreciable cause of error in testing on the lower levels. Perhaps one of the important deficiencies of the less alert college student is his lack of a nice language facility. But even the language correlation is not large enough to be other than suggestive. Perhaps a study of the contrasting groups would reveal conditions of some significance. The means of high school work of the *highest one hundred* and the *lowest one hundred* individuals of the group were ascertained. The results show that the mean Freshman of the highest hundred attended a high school whose mean salary for teachers was $1,671. The mean number of students was 517. He had secured credit during his high school career for the following units of work:

English	3.71	units
Vocation	3.07	"
History	2.95	"
Language	2.60	"
Mathematics	2.59	"
Science	2.15	"

The mean Freshman of the lowest hundred graduated from a high school whose mean salary was $1,666.75. The student body numbered 436.16. He presented for entrance into the University of Kansas the following preparatory units:

Vocation	4.02	units
English	3.74	"
History	3.20	"
Mathematics	2.19	"
Science	2.05	"
Language	1.43	"

Again there is something of the same condition, a tendency for the less alert student to crowd into courses of vocational subjects and history, and to avoid courses in foreign language. But even in these contrasting groups the differences are not clear cut. Only the most tentative conclusions could be drawn. On the whole, it would seem that we have found only some pertinent suggestions in the academic history of these selected Freshmen, which might explain the differences in their intelligence scores.

IV. The "Practice Effect"

In any consideration of test scores as indices of maturation, we must continually keep in mind that we are measuring a condition which is supposedly more or less constant. Although a child's height will increase with advancing months it is not a matter of daily fluctuation. We must also not forget that we are measuring this presumably fixed or slowly changing endowment, by a function or group of functions which may fluctuate under the influence of diverse factors. As an analogy, let us assume that we are compelled to measure a child's "altitudinal maturation", or height, by his ability to reach certain marks upon a wall. It is obvious that, in addition to the length of the bones and the gross structure of the skeleton, many other factors will enter into the situation. The pelvic alignment, the flexibility of clavicle and scapula in the shoulder ensemble, the general condition of the organism, the motivation of the child, will be conditioning factors of the final score. Assume that one child has acquired the trick of standing, in ballet dancing style, squarely on the end of her toes. It is evident that her score will be altogether out of proportion to her actual skeletal maturation which is usually measured in 'height'.

In measuring intelligence we judge maturation by a group of products which are conditioned by several factors in addition to that of maturation. Chance errors, especially at the time of the initial test, are much in evidence. The writer knows individuals who have explained low initial scores upon the basis of distraction due to the novelty of the situation, anxiety, fatigue, illness, lack of effort, and intoxication. These factors must be admitted, endured and ignored. When the initial testing is confined to a single session, we have no reliable technique by which they can be 'partialed out'. We can find comfort in this study, however, by noticing that the scores produced each fall by incoming Freshmen have always exhibited a fairly symmetrical surface. While the chance error is in evidence, it has produced no extraordinary skewness on the low side of our distribution.

Another factor is more serious. It is that of 'test wisdom'

or a technique in taking tests, the possession of which is a tremendous asset. The writer knows a junior highschool boy who, because of the family interest in mental measurements, has been the victim of many testings from early infancy. His score on the National Council tests would give him a mental alertness high among the college Freshmen of the nation. No small factor of advantage in his case is that he can 'get the idea' in a very hasty reading of the directions. He possesses, through frequent testings, that technique for taking tests, a test wisdom which is, we believe, something entirely different from his mental alertness when applied to other situations. Like the ballet dancing girl, he has acquired the trick of standing squarely on the end of his intellectual toes and of utilizing all of his inches to make a 'high mark'.

Granting that practice effect exists, several pertinent questions demand consideration. Does it arise after a single testing? Does the facility, like swimming or bicycle riding ability, remain with us indefinitely, or does it fade with time? How much of the gain of the retest must be allotted to this influence and how much to 'maturation'?

It has been possible to repeat Thorndike's procedure in considering the question. It will be remembered that he, in his high school retesting program, found among the scores of his second test numerous individuals who for some reason had not taken the first test. He assumed that these were equal in ability to the others and that the superiority of the score of the second-time tested students was due to the practice effect of the previous testing.

At the time of the testing of the 1927 examinees at the University of Kansas, the students were asked to designate whether or not they had ever taken a similar examination. Of these we were able to find forty-nine seniors, two hundred forty-six juniors and one hundred eighty-seven sophomores. We can find no reason for assuming these students to be any less intelligent than the students of the same college standing who had undergone a second testing. If we grant this, then the superiority of the *retest* scores over the *initial* scores of the new arrivals can be due

to nothing else than " practice effect " of the first testing. From the data on hand at that time we were able to make the following comparison. The data in detail may be found in Tables XIII, XIV, and XV.

TABLE XIII

61 Seniors (retested after 3 years)		Mean *Tc*	57.9
S.D.	9.6		
S.D.M.	1.23		
49 Seniors (initial test)		Mean *Tc*	54.4
S.D.	8.15		
S.D.M.	1.16		
Difference (due to practice effect)			3.5
S.D.D.	1.69		
EC	.75		

TABLE XIV

31 Juniors (retested after 2 years)		Mean *Tc*	57.15
S.D.	10.43		
S.D.M.	1.74		
246 Juniors (initial test)		Mean *Tc*	52.54
S.D.	8.4		
S.D.M.	.53		
Difference (due to practice effect)			4.61
S.D.D.	1.8		
EC	.9		

TABLE XV

130 Sophomores (retested after 1 year)		Mean *Tc*	55.3
S.D.	9.4		
S.D.M.	.82		
187 Sophomores (initial test)		Mean *Tc*	50.3
S.D.	8.8		
S.D.M.	.64		
Difference (due to practice effect)			5.
S.D.D.	1.04		
EC	1.7		

These differences with their very good reliabilities give us the measurement for the ' fading of a facility '.

One year	—5.0
Two years	—4.6 (used as 4.5 for ease of computation)
Three years	—3.5

After these corrections had been established we were able to check them by an examination of the Friends Freshmen repeated nineteen hours after the first test. The gain of second testing over the first was found to be 5.14 *Tc*. It seems that in estab-

lishing our correction for practice at the end of one year at a figure which is approximately equal to the established practice effect for one day, we have met every demand of scientific conservatism.

V. The Advantage of the Same Form for Initial Test and Retest

A number of retests were made with the same form as the original tests. By the method of equated groups it has been possible to measure the effectiveness of the use of the same form as a factor of advantage in the final score. We can also trace the fading of this factor with time. We can compare equated groups who were retested with the same and with different forms over the following time intervals:

1. Immediately after the first test.
2. After a three weeks' interval.
3. After a nine weeks' interval.
4. After one semester's interval.
5. After a one year interval.

1. The Advantage of the Same Form in an Immediate Retesting. These data were secured in February, 1921, by Professor Isabel Crabb and Professor Austin C. Cleveland at Friends University.

On the basis of their initial scores taken in September, 1928, one hundred Freshmen were approximately equated into two groups. The initial test was made with the 1928 form. In retesting, the experimenters used the 1927 form.

One group, which we will designate as the *S* or study group, was assembled an hour before the other, *N* or non-study group. It was explained to the *S* group that in one hour they would be given a psychological examination. As preparation for that event they would be allowed to study on the form during that hour. They could use scratch paper but were to make no marks upon the form itself; they could distribute their time among the tests as they pleased; they were to study intently for one hour. At the close of the hour they handed in the forms, passed to another hall, and in company with the *N* or non-study group, went through the standardized procedure of the test. The study group

took no results of the hour study, in scratch paper form, with them to the final examination.

In order to make the comparison equitable, the writer is conscious that the *N* group should have spent an hour, likewise, upon a still different form. Since the experiment was not, at the beginning, specifically planned for this purpose and since the additional forms were not available at the time of the experiment, we must accept the results for what they are worth. The writer believes that such a procedure would not have changed the results to any great degree. From the two groups we were able to equate exactly thirty-four pairs. We report here the means of these equated groups. The contrast of these two groups is as follows:

Retest Mean of *S* Group		56.91
S.D.	7.4	
S.D.M.	1.269	
Retest Mean of *N* Group		51.01
S.D.	6.66	
S.D.M.	1.142	
D—(Gain from an hour study)		5.9
S.D.D.	1.7	
EC	1.24	

2. The Four Weeks Interval. Among the laboratory students who were retested, there was a group composed of those who had recently entered the University. From these we can equate two groups of thirty-eight. One of them was retested on the same form, the other on a different form from the one used in the initial test four weeks previously. The data for these groups can be seen in the following:

Mean of same retest group		59.53
S.D.	10.21	
S.D.M.	1.65	
Mean of different retest group		56.2
S.D.	8.99	
S.D.M.	1.46	
D (Advantage for same form)		3.33
S.D.D.	2.2	
EC	.66	

3. The Nine Weeks Interval. During the ninth week after the initial tests, one hundred ninety Freshmen men were retested. One hundred seventeen used the same form, seventy-three used

another form. Because of the necessity of fitting our program to the University schedule, we cut the testing time to forty minutes. One-fifth was deducted from the standard time of each of the subtests. This fact will complicate any conclusion which might be drawn from the scores but probably does not impair any findings as to the relative standing of the two groups. In might be argued that if one group gains a certain amount in forty minutes they would gain more in sixty minutes. The work of Ruch and Koerty, with the use of differently colored pencils during various periods of extended time, would indicate that the production curve is fairly well flattened out during the final periods of each subtest. We do not believe that any extension of time would have increased the difference significantly. For the purpose of our comparison, two groups of fifty each were equated exactly. We find:

Retest mean of the same form		50.77
S.D.	9.29	
S.D.M.	1.31	
Retest mean of different form		46.6
S.D.	7.64	
S.D.M.	1.08	
D (Advantage of same form)		4.17
S.D.D.	1.69	
EC	.88	

4. *One Semester Interval.* Of the laboratory students who were retested in March, fifty had received their initial tests in September. These were retested on the same form. We have data on forty-seven Freshmen at Friends University who were tested in September on the 1928 form and retested in February on the 1927 form. The Friends students are Freshmen; the Kansas University students are, in the main, Sophomores. From these two groups thirty pairs are equated.

Mean of retest on same form		54.7
S.D.	8.24	
S.D.M.	1.5	
Mean of retest on different form		51.6
S.D.	7.42	
S.D.M.	1.35	
D (Advantage of same form)		3.1
S.D.D.	2.01	
EC	.55	

5. One Year Interval. Of the one hundred eighty who were retested after one year, eighty-eight used the same form (1926). From these, forty-one pairs were equated.

Same retest mean		57.52
S.D.	7.97	
S.D.M.	1.24	
Different retest mean		58.21
S.D.	8.92	
S.D.M.	1.39	
D (Advantage of same form)		—.69
S.D.D.	1.86	
EC	.13	

The writer would have preferred to have based the equating of the groups on more data than the initial scores. However, he believes that the consistently decreasing differences, together with the fairly good reliabilities of the means, justifies the confident statement that in one year's time any advantage which may result from the use of the same form has completely vanished.

VI. Relation of Time Interval and Gains

Having established the fact that no deduction need be made for repeating the same form after one year and having established a correction for practice, we have now to notice the relation of the gains to the time interval between the tests and retests.

1. Three Year Interval. We have retests for one hundred thirty individuals with a time interval of three years between tests. These are distributed among the following classes:

Seniors	90
Juniors	22
Sophomores	18
Total	130

Ignoring class lines we find:

Retest mean		57.42
S.D.	10.11	
S.D.M.	.88	
Initial test mean		50.83
S.D.	7.5	
S.D.M.	.675	
Difference		6.59
S.D.D.	1.1	
EC	2.15	

2. Two Year and One Semester Interval. For this time interval we have twenty individuals, seven Juniors and thirteen

Sophomores. It is a very small group with very low reliabilities. We find:

Retest mean		51.45
S.D.	7.23	
S.D.M.	1.61	
Initial test mean		47.87
S.D.	4.33	
S.D.M.	.96	
Difference		3.58
S.D.D.	1.87	
EC	.68	

3. Two Year Interval. In this grouping we have one hundred seventeen individuals.

Seniors	21
Juniors	68
Sophomores	28
Total	117

Retest mean		57.25
S.D.	9.77	
S.D.M.	.9	
Initial test mean		
S.D.	8.07	
S.D.M.	.74	
Difference		7.08
S.D.D.	1.44	
EC	2.23	

4. One Year and One Semester Interval. With the one year and one semester interval we have one hundred fifteen students. All are Sophomores.

Retest mean score		54.08
S.D.	8.69	
S.D.M.	.81	
Initial mean score		48.21
S.D.	7.23	
S.D.M.	.67	
Difference		5.87
S.D.D.	1.05	
EC	2.01	

5. One Year Interval. The group retested after one year consists of two hundred forty-nine individuals, distributed among the classes as follows:

Sophomores	203
Juniors	11
Seniors	35
Total	249

Retest mean score		56.74
S.D.	9.05	
S.D.M.	.57	
Initial test mean score		49.44
S.D.	8.6	
S.D.M.	.54	
Difference		7.3
S.D.D.	.78	
EC	3.36	

6. One Semester Interval. For the one semester group we have forty-seven individuals.

Retest mean score		50.88
S.D.	7.48	
S.D.M.	1.09	
Initial mean score		47.3
S.D.	8.27	
S.D.M.	1.2	
Difference		3.58
S.D.D.	1.62	
EC	.79	

Here we find a group totally at variance with the general tendency of other groups.

7. Four Weeks Interval. In this group we have one hundred eighteen individuals.

Retest mean score		59.54
S.D.	10.85	
S.D.M.	.99	
Initial mean score		54.00
S.D.	9.28	
S.D.M.	.85	
Difference		5.53
S.D.D.	1.3	
EC	1.53	

8. One Day Interval. This group of one hundred thirteen Freshmen at Friends University were retested with a *Zwischenzeit* of about eighteen hours.

Retest mean		50.01
S.D.	9.87	
S.D.M.	.92	
Initial test mean		44.86
S.D.	9.42	
S.D.M.	.88	
Difference		5.15
S.D.D.	1.27	
EC	1.45	

An examination of the appended chart reveals the fact that for some reason the students with the one, three, and five semester

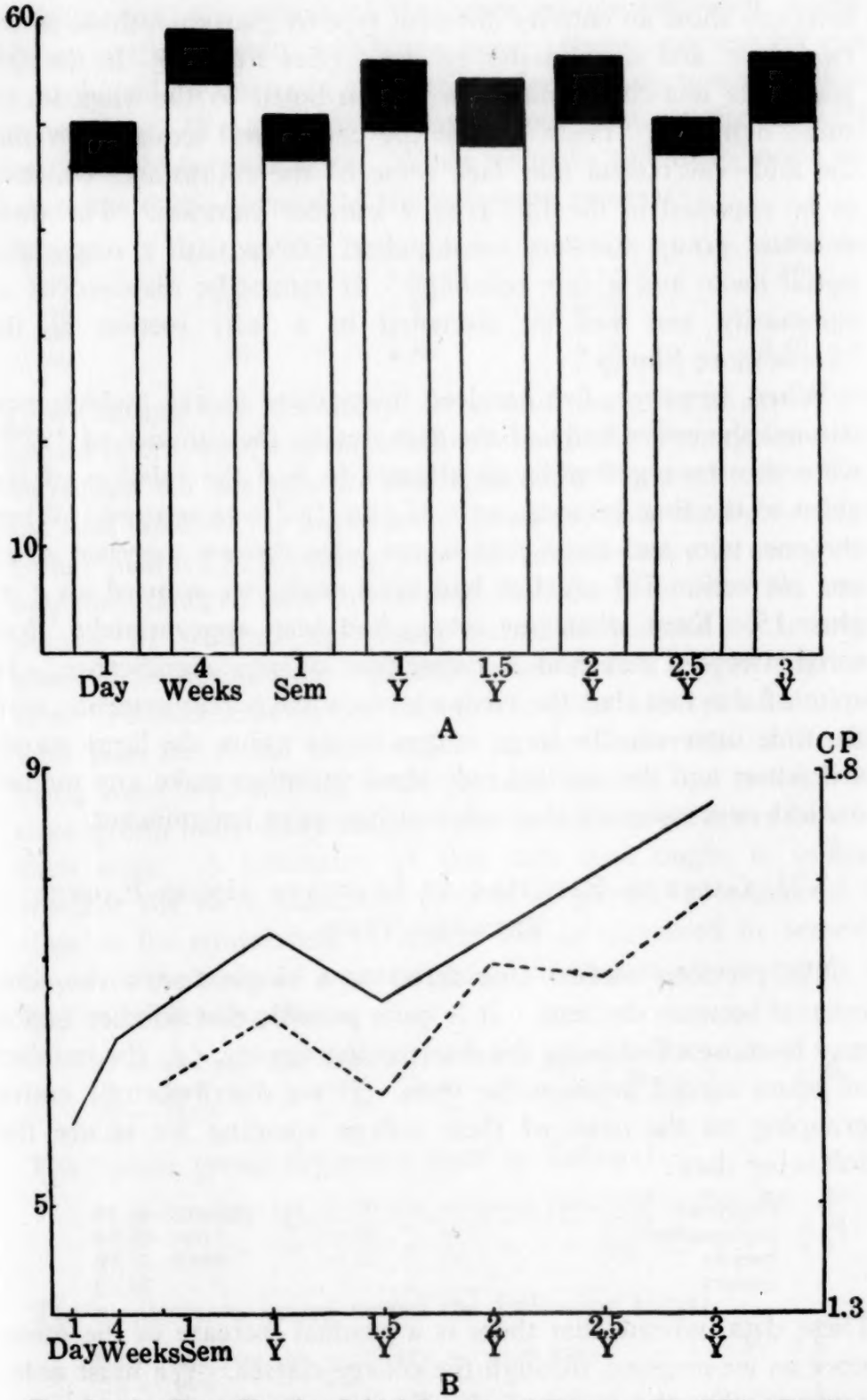

FIG. 1. A. Chart Showing Initial Scores and Retests. The White Portion Represents Initial Scores; Black, Gain.

B. Curve Showing Gains in Relation to Time Interval (solid line) and Scholarship by Semesters (dashed line) in Relation to Time Interval. CP, Credit Points.

intervals show an entirely different type of gain than those of the two, four, and six semester groups. (See Fig. 1.) In the first place this non-conformity can be attributed to the vagaries of small numbers. There is also the conjectural explanation that the mid-year retests may lack some of the enthusiasm which is to be expected in the fall after a summer vacation. The three semester group numbers one hundred fifteen with a respectable initial mean and a fair reliability. It cannot be disposed of so summarily and will be discussed in a later section as the 'Sophomore Slump'.

When, however, five hundred thirty-three scores (which constituted the entire body of the data during the summer of 1929) were thrown together in an attempt to find the relation of the gains to the time interval, an r of plus .067 was secured. When the one, two, and three year scores were thrown together, after our correction for practice had been made, we secured an r of plus .15. Even when our scores had been appropriately 'doctored' we did not find a correlation of any significance. In spite of the fact that the means show some correspondence with the time intervals, the large ranges of the gains, the large standard errors and the marked individual variation make any mathematical expression of that relationship quite insignificant.

VII. Gains in Relation to Semester Hours Earned Between Tests

The previous section considered as a single factor the time interval between the tests. It is quite possible that another factor may be more effective as the determining agency, *i.e.*, the number of hours earned between the tests. If we distribute our entire grouping on the basis of their college standing we secure the following data:

Freshmen	Mean	48.45
Sophomores	"	55.74
Juniors	"	57.08
Seniors	"	59.23

These data indicate that there is a gradual increase in the mean score as we progress through the college classes. We must note, however, that the mean of the Freshman group is based upon

initial scores; the means of the other groups are retest scores. Hence any superiority which the upper classes may exhibit can be explained on the basis of practice effect or selection as well as maturation. We are able to classify our data on the basis of hours earned between tests. When we make this distribution we secure the data indicated by the following summary:

Hours	Number	Mean Gain	S.D.D.	Cor. for Practice
30	285	7.00	.72	2.00
45	115	5.87	1.05	
60	111	7.38	1.14	2.88
90	90	6.90	1.28	3.40

If we assume that the thirty, sixty, and ninety hours have been earned in one, two, and three hours respectively we may make our correction for the practice and secure the "growth curve" of the final column. It would seem, however, that we are not altogether justified in assuming that our subjects have in every case used the standard time for earning their credit hours. No small number of students have been compelled because of semester absences to extend their academic career over a longer length of time. Also because of the fact that a great number of students who take the initial examination at the University of Kansas bring some credits from other schools, we can find within each class group individuals with a varying number of hours between their tests. A tabulation of this data then ought to indicate whether the mere automatic process of growth as measured by time or the stimulation of college life as measured by semester hours is the basis of maturation. Within our senior group we find the following facts:

35 — one year int. — 30 hrs. — mean gain 5.9 — Cor. Pr. .9
21 — two " " — 60 " — " " 7.79 — " 3.29
90 — three " " — 90 " — " " 6.9 — " 3.4

The Junior group organizes itself as follows:

11 — one year int. — 30 hrs. — mean gain 5.22 — Cor. Pr. .22
68 — two " " — 60 " — " " 7.13 — " 2.63
22 — three " " — 60 " — " " 7.8 — " 4.3

The Sophomore group reveal the following facts:

203 — one year int. — 30 hrs. — mean gain 7.6 — Cor. Pr. 2.6
28 — two " " — " " — " " 6.4 — " 1.9
18 — three " " — " " — " " 3.6 — " .1

The data of these tabulations admit of diverse interpretation. The Sophomore tabulation indicates that with college hours held constant the time interval between tests will cause a decline. If the other groups would show the same tendency the significant interpretation is that stimulation and not time causes maturation. The Junior group indicates that in spite of the fact that during the three years between tests the number of college hours only equalled that of the two year group, maturation seemed to continue throughout this time interval.

VIII. Correlations

The problem of this section is to ascertain by correlation technique whether or not there are any factors of the college environment which are exclusively associated with scores and gains.

The first problem is something of an excursion into a by-path from the main study. The writer was interested in learning the value of the tests as prognostic of scholarship. Then the query arose as to whether the test at the close of an academic period correlated any more closely with the quality of the students' scholarship than the test at the beginning of the period. At this phase of the study we had at hand the detailed academic histories of ninety-nine Senior College students. Because the hours were not constant we resorted to the partial correlation technique and utilized the three factors: test scores, semester hours, and credit points. We will designate Test scores as 1, Semester Hours as 2, and Credit Points as 3. Using the initial test as the basis of our comparison we have:

r of 1 and 2 equals —.03 (scores and hours)
r of 1 and 3 equals .34 (scores and credit points)
r of 2 and 3 equals .45 (hours and credit points)
r of 12.3 equals —.21
r of 23.1 equals .48
r of 13.2 equals .39

Our significant correlation is the last one. Scholarship and test scores, with hours held constant, correlate with a positive coefficient of thirty-nine. Using the final scores as a basis we have:

r of 1 and 2 equals .001
r of 1 and 3 equals .39
r of 2 and 3 equals .45

Resorting again to the partial correlation technique we find:

r of 12.3 equals —.21
r of 23.1 equals .48
r of 13.2 equals .44

It is an interesting coincidence that the r of 12.3 is the same in both cases. The conclusion of the study shows:

r of 13.2 of the initial test is .39
r of 13.2 of the final test is .44

Thus we find that the final test score shows itself only slightly superior to the initial score as an index of scholastic quality.

Our first thought was that the gains might be proportionate to the total number of semester hours earned at the time of the retest. This idea was explored by partial correlations using the variables: (1) gains—or difference between initial test and retest scores, (2) total semester hours at the time of retesting, (3) time interval between tests. Gains were tabulated in .5 *Tc* steps; time in one-half year intervals (one semester used as a half year); and hours grouped as follows:

0—15	46—60	76—90
16—30	61—75	91—105
31—45		

At the time of this calculation we had data on five hundred thirty-two individuals. Designating time as 3, hours as 2, and gains as 1, we have:

r of 3 and 2 equals .555
r of 1 and 3 equals .0676
r of 1 and 2 equals .0136

Partialing gives us:

r of 13.2 equals .07
r of 12.3 equals .028
r of 23.1 equals .555

Certainly the above coefficients can not be construed to express any other than a chance relationship.

The next suggestion was that the influential factor might be the number of semester hours earned between tests. Following the same procedure we find:

r of 3 and 2 equals .837
r of 1 and 3 equals .03
r of 1 and 2 equals 14

Partialing gives:

r of 13.2 equals —.117
r of 12.3 equals —.172
r of 23.1 equals —.838

Here we find a suggestion that semester hours earned between tests are possibly associated with gains in scores but the coefficient of correlation is too small to be of any significance.

The next hypothesis was that the large "practice effect" of those tested over the one year interval was tending to conceal any relationship which might exist and that the utilization of our 'correction for practice' might reveal a more significant correlation. Accordingly, we selected the students with the one, two, and three year intervals and ignored those with the one, three, and five semester intervals. This left a total of three hundred forty-six cases. Five *Tc* was deducted from the gains of all individuals with a time interval of one year; four and five-tenths *Tc* from the gains of individuals with a two year interval; and three and five-tenths *Tc* from all those with a three year interval. With gains designated as 1, hours 2, and time 3, we have these correlations:

r of 2 and 3 equals .803
r of 1 and 3 equals .151
r of 1 and 2 equals .194

Partialing gives:

r of 23.1 equals .71
r of 13.2 equals —.007
r of 12.3 equals .122

Again this time, with our scores appropriately 'doctored' we find a correlation of no significance.

Next it was thought that perhaps the social activities of college life might be as effective as the curricular activities. From the current number of the college annual we were able to obtain information as to the various "student activity" interests of forty-eight of the Seniors in our data. A social index was devised on the following basis:

Membership in social fraternity or sorority — 3 points
Membership in professional fraternity — 2 points
Membership in any other organization — 1 point

The correlation of this index and the gains was negative twelve.

Our next suggestion was that the quality of scholarship as measured by credit points might be found to show a relationship. Accordingly, detailed information was secured for sixty-eight Seniors, fifty-two Juniors, and one hundred nineteen Sophomores—a total of two hundred thirty-nine. Partial correlations were made with the four factors numbered as follows: gains 1, hours 2, credit points 3, time interval 4. These zero correlations were found:

r_{12} equals .11 (gains and hours)
r_{13} " .16 (gains and credit points)
r_{14} " .09 (gains and time)
r_{23} " .86 (hours and credit points)
r_{24} " .98 (hours and time)
r_{34} " .81 (credit points and time)

Correlations of the first order are found to be:

$r_{14.3}$ equals —.06 (gains and time — cr. pts. held constant)
$r_{24.3}$ " .94 (hours " " " " " ")
$r_{12.3}$ " —.05 (gains and hours— " " " " ")
$r_{14.2}$ " —.09 (" " time — hours held constant)
$r_{34.2}$ " —.32 (cr. pts. and " " " " ")
$r_{13.2}$ " .13 (" " " gains " " " ")

(Other six first order correlations are not used)

Correlations of the second order which are concerned with the problem of gains are as follows:

$r_{12.34}$ equals .001 — gains and hrs. — cr. pts. and time con.
$r_{13.24}$ " .107 — " " cr. pts. — hrs. " " "
$r_{14.23}$ " .05 — " " hrs. — cr. pts. " hrs.

The significant correlation of gains and credit points, with hours and time held constant, is only .107. Again we find what appears to be only a chance relationship.

In the above computations it must be remembered that out of the entire group of two hundred thirty-nine, one hundred nineteen or one-half are Sophomores. It is with this one year group that the so-called practice effect is most conspicuous. We must recognize that this *test wisdom* represents a very specialized capacity. It develops very rapidly and fades slowly for the first year. It is obvious, then, that these erratic changes in scores will effectually and hopelessly conceal the more steady and fundamental 'increment of capacity'. When we examine the status of our Seniors we find a different condition. We know that the practice effect has faded considerably in three years. We know also that, with

the accumulation of approximately ninety hours of college credit, a greater number of credit points will accrue to each student and the differentiation of scholastic capacity can be made with nicer discrimination. When we combine our entire group it will be readily seen that the Sophomores, who constitute half the group, with their large and chance controlled practice effect, will effectually conceal whatever relationship might be revealed by the increasing number of credit points of the Juniors and Seniors. Since we cannot partial out the practice effect our only procedure is to compute the correlations of the Sophomore, Junior and Senior groups separately. If we find the correlation between credit points and gains greater for the Juniors than for the Sophomores and greater for the Seniors than for the Juniors, we can conclude that with the increase in academic standing, the gains in test scores are representing less and less the growth of test wisdom and more and more that genuine maturation which is the object of our concern.

In pursuance of this hypothesis we were able to establish the following groups with the designated classification and time interval:

119 Sophomores — one year interval
52 Juniors — two year interval
68 Seniors — three year interval

In our Sophomore group, designating gains as 1, hours as 2, and credit points as 3, we find:

r of 1 and 2 equals .01
r of 1 and 3 equals .04

The correlation is not high enough to justify the partialing procedure. It is very evident that the practice effect and chance errors are overbalancing and concealing any influence which might come from either semester hours or credit points. In the Juniors group we have the following correlations:

r of 1 and 2 equals .13
r of 1 and 3 equals .28
r of 2 and 3 equals .66

Correlations of the first order gave:

r of 12.3 equals —.07
r of 13.2 equals .26
r of 23.1 equals .65

Here we find no evidence of any increase in the significance of hours, but a very emphatic increase in the significance of the credit points.

In the Senior group are found these correlations:

r of 1 and 2 equals .2
r of 1 and 3 equals .41
r of 2 and 3 equals .47

Partialing gives:

r of 12.3 equals .009
r of 13.2 equals .36
r of 23.1 equals .43

In this we find an increasing significance in the credit points, a correlation of plus .36. The question at once arises as to just how significant is a correlation of plus .36. In this regard it is interesting to note the decreasing correlation of credit points and hours. In the Junior year we find this correlation to be .65; in the Senior year it is only .43. If, with the very definite relationship between hours and credit points, we find the correlation decreasing and at the same time we find the correlation of gains and credit points increasing, we must assume that there is some definite relationship between these two factors.

In concluding this section we may summarize our findings as this: We have been able through the correlation to find no fixed association between time and gains or between semester hours and gains; we do find a very definite correspondence between the quality of the student's scholarship and the gain made in undergoing a second psychological examination.

IX. The Location of the Gains

It is the problem of this section to ascertain just where in the group the large and small gains are located. Naturally the first question is whether or not the entire group move up uniformly. Using the data on hand in July, 1929, the correlation formula reveals the following:

61	Sr.	—3	yr.	int.	—r	of	initial	test	and	retest	.78
36	Jr.	—2	"	"	—r	"	"	"	"	"	.92
130	Soph.	—1	"	"	—r	"	"	"	"	"	.85
113	Fr.	—1	"	"	—r	"	"	"	"	"	.86

The next inquiry was to ascertain whether or not the size of the initial score would be any index as to the amount of gain. Using the sixty-one Seniors whose retest scores were available during the summer of 1929, we find *r* of the initial scores and gains to be a plus .124. This indicates in the entire group that the amount of the gain bears little relation to the size of the initial score.

It will be remembered that the *Tc* scores are S.D. units. All scores in the 30's are minus 2 S.D. scores. All scores in the 40's are minus 1 S.D. scores. The scores in the 50's are plus 1 S.D. scores, while the scores in the 60's are plus 2 S.D. scores. It is important to learn the mean gains of these groups over the various time intervals. We will omit our scores in the 20's and 70's where our frequencies are insignificant. The following tabulation brings out these facts: the high and low sections, *i.e.*, those whose initial scores are in the 30's or 60's, have a gradient entirely different from those individuals who are grouped more closely to the mean.

Gains Tabulated on Basis of Initial Test

Time Interval	I.T. 30–39.5	I.T. 40–49.5	I.T. 50–59.5	I.T. 60–69.5
1 day	No. 8	No. 32	No. 40	No. 23
	M. Gain 8.37	M. Gain 5.32	M. Gain 5.83	M. Gain 6.06
	S.D. 6.15	S.D. 3.5	S.D. 3.5	S.D. 4.12
	S.D.M. 2.17	S.D.M. .62	S.D.M. .55	S.D.M. .9
1 year	No. 27	No. 87	No. 97	No. 23
	M. Gain 9.66	M. Gain 7.75	M. Gain 7.19	M. Gain 7.63
	S.D. 5.88	S.D. 4.5	S.D. 3.6	S.D. 7.63
	S.D.M. 1.13	S.D.M. .48	S.D.M. .37	S.D.M. .78
1½ years	No. 7	No. 54	No. 36	No. 4
	M. Gain 9.07	M. Gain 6.49	M. Gain 7.0	M. Gain 8.75
	S.D. 4.92	S.D. 4.0	S.D. 4.0	S.D. 2.96
	S.D.M. 1.86	S.D.M. .54	S.D.M. .67	S.D.M. 1.48
2 years	No. 9	No. 46	No. 36	No. 16
	M. Gain 8.67	M. Gain 7.0	M. Gain 7.38	M. Gain 11.0
	S.D. 4.03	S.D. 3.77	S.D. 3.6	S.D. 5.9
	S.D.M. 4.03	S.D.M. .55	S.D.M. .69	S.D.M. 1.47
3 years	No. 5	No. 39	No. 55	No. 13
	M. Gain 9.1	M. Gain 7.38	M. Gain 7.72	M. Gain 11.19
	S.D. 3.4	S.D. 4.7	S.D. 7.4	S.D. 3.98
	S.D.M. 2.42	S.D.M. .75	S.D.M. .55	S.D.M. 1.1

The writer regrets that the population of each of these groups is not larger. The reliabilities are not as high as he would like.

But uniform relation standing through all of the time intervals justifies him in thinking that a greater number of cases would reveal the same tendency more emphatically.

X. The Equated Groups Procedure

The previous section seemed to indicate that the amount of gain of the retest is a function of the quality of the student. With both the high and low groups making the larger gains, and with the slope of the two central groups less steep, it is easy to see that any computation involving the group as a whole will show contradictory results. By the equated groups procedure it will be possible to hold constant this qualitative factor and thus measure the effect of the other factors. Against the one-day group we are able to equate five groups at the following time intervals: four weeks, one year, one year and one semester, two years, and three years. The frequencies of these groups is sixty-two. The writer would have been glad to have equated these on the basis of information additional to that of the initial score. This was impossible. The amount of gain through the various time intervals is revealed by the following table:

1 day	— mean gain	5.77	— S.D.	2.96	— S.D.M.	.37
4 weeks	— " "	6.54	— "	3.67	— "	.46
1 year	— " "	7.52	— "	3.41	— "	.43
1½ years	— " "	6.84	— "	3.75	— "	.47
2 years	— " "	7.48	— "	4.07	— "	.51
3 years	— " "	8.69	— "	4.06	— "	.51

If we consider the gain of one day due wholly to practice effect the superior gain of the other groups should be due to maturation. We notice then these excess gains over the one-day group:

4 weeks	— excess gain	.77	— S.D.D.	.59	— E.C.	.47
1 year	— " "	1.75	— "	.57	— "	1.1
1½ years	— " "	1.07	— "	.59	— "	.64
2 years	— " "	1.71	— "	.63	— "	.97
3 years	— " "	3.12	— "	.63	— "	1.78

On the whole these mean gains do not seem to be large. We find in three years an excess gain over the one day group of 3.12 *Tc*. But we must remember that the *Tc* Scores are rather consolidated scores, the units representing considerably more than raw point scores. Dr. Teagarden (3) investigated the maturation of individuals from the ages of thirteen to eighteen. She

formed a composite of the Binet, Alpha, Pressey, and Stenquist tests through the *Tc* Score technique. Her age means are as follows:

Age	*T* Score
13	48
14	47
15	51
16	54
17	53
18	56

Here we have a gain in five years of eight *T* Scale units. When we compare this with our three year gain in college, which averages 1.04 *T* Scale units, we can find no marked flattening of the maturation curve through the college years.

XI. The "Sophomore Slump"

It has been noted that the retests of the three semester group failed to show the gains of those retested at the beginning of the year. If we take our entire distribution we find that the three semester group falls to a gain of 5.87 *Tc* as contrasted with the 7.3 *Tc* gain of the one year group or the 7.08 *Tc* gain of the two year group. When we observe our equated group curve we find that the gain of the one and one-half year group amounts to 6.84 *Tc,* which contrasts with the 7.52 *Tc* gain of the one year group or the 7.48 *Tc* gain of the two year group.

Mr. Roy L. Roberts (4), graduate student in Psychology of the University of Kansas, has made an interesting study of the scholarship quality of two hundred graduates of the University of Kansas; one hundred from the College of Liberal Arts and one hundred from the School of Engineering. The average scholarship in terms of average credit points, for the eight semesters, is tabulated in the following table:

Engineers		College	
First Semester	1.60	First Semester	1.51
Second "	1.60	Second "	1.57
Third "	1.36	Third "	1.50
Fourth "	1.41	Fourth "	1.62
Fifth "	1.41	Fifth "	1.61
Sixth "	1.54	Sixth "	1.69
Seventh "	1.53	Seventh "	1.74
Eighth "	1.71	Eighth "	1.81

These data bring out quite distinctly the "Sophomore Slump" so frequently recognized in college tradition. When we superimpose the curves of scholarship upon the curve of gains in *Tc* scores we find a most significant uniformity in the third semester drop. Since the curve of intelligence score gains does not represent the same persons and since the personnel of Mr. Roberts' study is not at all identical with this study, it seems certainly more than mere chance that the third semester should establish itself as the low water mark in three types of intellectual activity.

XII. Conclusion

As a result of these studies we are able to make the following conclusions: The ability to make test scores seems to increase during the college years.

The factor of individual differences is very evident. Extreme differences between initial and retest scores are frequent. They are as frequent in the one day interval as in the three year interval. Any attempt at serious guidance of a student based upon the result of a single testing carries with it a probability of a serious injustice to the student.

The curves of the gains carried through the college years resembles very much the negatively accelerated curve known as "the typical learning curve". We find the sharp initial rise followed by the general flattened curve which in turn is followed by another ascent.

The decreased gains of the three and four semester interval groups indicate a retardation of growth during the Sophomore year. Mr. Roberts' study, dealing with an entirely different personnel in a different line of procedure, emphasizes the same tendency. Perhaps the Freshman year is that epoch of social adaptation while the Sophomore year is the time of serious intellectual and attitudinal orientation into college life. We have found no evidence that the mere fact of time, that is, mere existence on the college campus, causes any increase in the capacity to make scores. There is a very decided indication that by the time a student has reached his fourth year his scholastic record, as

evidenced by his accumulated credit points, is a significant index of his maturation.

The amount of gain seems to be conditioned by the size of the initial score. Rather paradoxically the high and low initial scores make the largest gains. It is possible that the college has adjusted itself to the needs of the extreme students and has left the mediocre student to shift for himself.

If we accept the increase in capacity to make test scores as evidence of maturation, we may say that the college student matures quite rapidly at first, slumps somewhat during that period of stress and strain of college adolescence, the Sophomore year, begins to climb again with the Junior year. Our last data leave him climbing.

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THE MATURATION OF COLLEGE STUDENTS AS EVIDENCED BY THE EIGHT SEMESTER AVERAGE GRADE POINTS

by

ROY L. ROBERTS

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I. INTRODUCTION

This study considers the achievement of college students as revealed by the average grade points recorded semester by semester during the four years, in an attempt to determine whether there is a maturation or growth curve evidenced by a rise in the average grade points during this period.

II. PROCEDURE

A list of the graduates for the last several years was obtained from the Deans' offices—the engineers from the Dean of the School of Engineering and Architecture and the liberal arts students from the Dean of the College of Liberal Arts and Sciences. The lists of graduates were checked against the records of the scores made on the psychological examinations which have been given to all new students entering the university. If no record of the score was found the individual was not considered in this study. Furthermore the student must have been in residence at the university for eight consecutive semesters.

Otherwise it would have been very difficult and in some cases impossible to determine the average grade points by semesters. After making this selection we began at the beginning of the list and took each name in order until the number reported in this study had been checked.

In evaluating grades, 'A' was given a score of three points, 'B' two points and 'C' one point. No score was given for a 'D' while 'F' was scored as minus one. The numerical value for a grade was multiplied by a number of hours' credit for the course of study. In this manner the total number of grade points for each semester was determined. This number divided by the number of hours' credit received by the student for the semester's work gave the student's average grade point for the semester. The average grade point for the entire group was found by adding the average grade points of all the students and then dividing this sum by the number of students in the group.

The terms decile rating or decile grouping refer to the classification of the students on the basis of their scores on the psychological examination. The first decile includes the 10 per cent of the students taking the examination who made the highest scores; the tenth decile indicates the group making the lowest scores.

III. Engineering Students

This group includes 100 graduates of the School of Engineering and Architecture whose decile ratings were as follows:

Decile rank	Number of students
1st	14
2nd	20
3rd	16
4th	13
5th	9
6th	7
7th	7
8th	8
9th	2
10th	4
Total	100

One interesting fact brought out by this tabulation is that 50 per cent of the graduates were in the upper 30 per cent of the student body which took this test as freshmen.

The average grade point by semesters for this group was as follows:

Semester	Average grade point	Standard deviation
1st	1.61	0.72
2nd	1.61	0.75
3rd	1.36	0.82
4th	1.41	0.81
5th	1.41	0.77
6th	1.54	0.74
7th	1.53	0.73
8th	1.71	0.64

It will be noticed that this group maintained a consistent average grade point record during their freshman year. However, during their first semester as sophomores they fell 0.25 of a grade point or 15.5 per cent below their record for the freshman year. Several new factors enter the student's experience during this period which may offer some explanation of the sudden drop. The work taken by the sophomores is much more difficult than that taken by the freshmen. In fact there is a greater jump in difficulty of subject matter between the freshmen and sophomore years than there is between any of the other years.

Perhaps another factor is that the students are now sophomores and must see that the freshmen are properly initiated into the mysteries of college and fraternity life. Many of the sophomores came to the university as freshmen with the idea that the work was very difficult. By hard and consistent work they made respectable records during their freshman year and they feel that they can now 'take things easy'.

Many of the students come to college to take 'engineering' and when they have to take work in English, mathematics, economics, physics and other more or less theoretical subjects whose value they do not comprehend or appreciate they become discouraged for a time and slacken their pace.

All students, however, do not participate in this sophomore 'slump'. Thirty-seven out of the 100 graduates have an equal or higher grade point for their first semester as sophomores as compared with their second semester as freshmen. The students who do not 'slump' are not confined to any one or more decile groups but are found in every decile except the ninth. The standard deviation in the grade points within a semester is also

much greater during the sophomore year than it is during any other year or semester.

After this initial 'slump' the curve is steadily upward and the group finished their senior year 0.10 of a grade point higher than they were as freshmen and 0.35 of a grade point higher than they were during their first semester as sophomores. In every year except the freshman year a fall-spring fluctuation is noticeable. The average grade point for the fourth semester is 0.05 higher than the third, the sixth is 0.13 higher than the fifth and the eighth is 0.18 higher than the seventh (see Fig. 1).

IV. College of Liberal Arts

One would ordinarily suppose that the vocational objective which is found in the school life of the engineers might make a difference in the results attained in their university work. In order to determine what difference, if any, existed between a group motivated by a definite vocational objective and one where

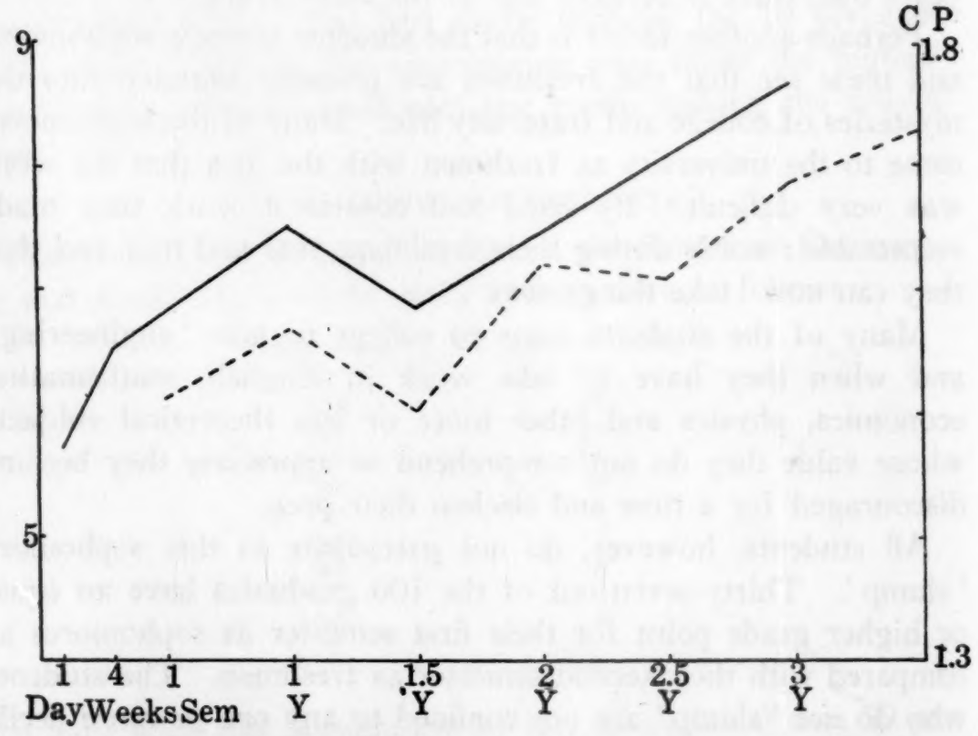

Fig. 1. Curve Showing Gains on Intelligence Tests at Different Time Intervals (solid line) and Grade Points by Semesters (dashed line). CP, Credit Points.

the vocational objective is not so apparent, the records of 100 graduates of the College of Liberal Arts were examined and a comparison made of the records of the two groups.

The decile rating of this group was as follows:

Decile	Number of students
1st	12
2nd	17
3rd	13
4th	12
5th	10
6th	7
7th	8
8th	8
9th	4
10th	9
Total	100

The principal difference in decile rating between this grouping and that of the engineers was that 9 per cent of the Liberal Arts graduates were in the tenth decile while only 4 per cent of the engineers were in this group. But on the whole the classification of the two groups was practically the same.

The average grade point by semester for this group follows:

Semester	Average grade point
1st	1.51
2nd	1.57
3rd	1.50
4th	1.62
5th	1.61
6th	1.69
7th	1.73
8th	1.81

About 3,000 individual grades which were given by a large number of instructors during the eight semesters were used in determining these average grade points. With a group of this size and diversification, the eccentricities in grades would tend to cancel out so that the average grade points should furnish a fairly reliable index of the actual achievements of the group.

Here again one will note the third semester slump but it is not as severe as the slump found in the group of engineers. In this group the slump was only 0.07 of a grade point while in the engineers it was 0.25 of a grade point. Fifty per cent of the Liberal Arts students do not participate in the third semester

slump while only 37 per cent of the engineers do not drop in grades during this semester. Probably the greater difficulty of subject matter and practically no chance for choosing elective courses accounts for the greater number and degree of slump among the engineers. The smallest number is found in the ninth decile where 25 per cent do not slump while the largest number is found in the tenth decile where 67 per cent do not drop in grade points.

If increased difficulty of subject matter is eliminated as a possible cause for the third semester slump and there seems to be no good reason why the third semester subject matter in the Liberal Arts College should be much more difficult than that found in the second semester, then the slump must be considered as a chance phenomenon or as a phenomenon which arises out of the social life of the community. If this group is classified on the basis of their affiliation or non-affiliation with fraternities and sororities it is found that 73 belong to one or more fraternities and sororities and that 27 do not belong to any fraternity or sorority. It might also be stated that practically all of the students in this group who held official positions in campus activities also belonged to one or more fraternities or sororities. Of the 73 who belonged to a fraternity or sorority 36 or 49 per cent participated in the sophomore or third semester slump; of the 27 who did not belong to a fraternity or sorority 14 or 51.8 per cent participated in the slump. This immediately reveals that membership or non-membership in fraternities or sororities has a slight if any connection with the drop in grade points. The above facts together with the further fact that 50 per cent of the students do not slump might indicate that this is a more or less chance fluctuation caused by factors, social and otherwise, which we have been unable to isolate.

For this group a fall-spring fluctuation occurs throughout the four years. The second semester is 0.06 of a grade point higher than the first, the fourth is 0.12 higher than the third, the sixth is 0.08 higher than the fifth and the eighth is 0.08 higher than the seventh semester.

This fall-spring fluctuation was also found by Miss Ruth

Byrns (1) who made a study of the grades of the undergraduate student body at the University of Wisconsin over a period of eight semesters extending from 1925–1926 to 1928–1929 in which a total of over 55,500 student averages were used. Among other things she found that " there is a marked tendency for the grades of every group to be higher in the second semester of each year than they were in the first semester. That students who do unsatisfactory work are dropped or voluntarily withdraw before the second semester is only one of the factors that produce this condition ". Miss Byrns thinks that much of this increase in the second semester is due to the fact, (1) that the students are better adjusted to university life the second semester than they are the first and (2) that there is a carry over where the courses are continued into the second semester. Only the two last mentioned factors could affect our study since we considered the same group throughout the eight semesters.

V. Factors Affecting Grades

How can we explain this gradual increase in the size of the average grade point? It is true that this increase is only a small absolute increase, but since it is an increase on the part of a large group, the small absolute increase becomes very significant. If the record of the unselected college group is considered as a sample, the absolute increase in size is only 0.31 of a grade point, possibly the difference between a C plus and a B minus, but if the first semester's average grade point is considered as a base then this increase is practically a 20 per cent increase in the mean of the *entire* group. An increase of that proportion is important.

This increase in size of grade point can be explained by showing, (1) that the change or development is due to changes in the instruments of measurement, (2) that it is due to changes in the phenomenon under consideration, or (3) that it is due to changes in both the instruments of measurement and the phenomenon being measured. We shall examine these various possibilities and see if we can discover what is actually happening.

One factor that must be considered is the basis for the comment that one frequently hears about the greater sophistication of upper-

classmen in the lore of how grades are determined. The upperclassmen have been at the university several years. They are better acquainted with the university methods and consequently are supposed to know more about how to do the work that the professors require. They frequently live at a fraternity where the problems and quizzes which the professors have given in the past are kept from year to year. This allows them to know with a reasonable degree of certainty what the professor expects. This is especially true where the professors have taught in the same university for several years and have become more or less set in their methods. This same condition, however, is also found among the underclassmen who live at the fraternities.

The juniors and seniors become acquainted with the ' readers ' in the various departments. This frequently allows them to exert an influence on their grades with a skill that the underclassmen do not possess. While the underclassmen may know the ' readers ' who grade their papers, they ordinarily do not have the ' influence ' or ' pull " of the upperclassmen. In other words, the assumption underlying this argument is that even though the juniors and seniors do the same quality or even a poorer quality of work than do the underclassmen, they obtain better grades because they are ' on to the ropes ' or ' have a pull '. How valid this assumption is no one knows definitely for it would be impossible to measure quantitatively social forces such as are mentioned above. However, the question may well be raised whether the changes which may be produced by the skilled use or manipulation of these forces is a change in the instrument of measurement or whether it is a development or growth in the students which gives them an increased insight into the factors influencing the instructor's rating of their achievements. The students live in a world which is influenced by social forces and learning how to recognize, evaluate, and use these social forces is just as much a part of their education as learning how to solve an algebra problem. Social factors condition all school achievements and must be considered in any study of the growth or development of intelligent behavior, whether that development be made in the freshman or in the senior year.

The argument is also advanced that the instructors grade juniors and seniors easier than they do freshmen and sophomores. The freshmen are not supposed to know very much when they come to the university and consequently they are put on the defensive. They must prove their case. Many instructors give them a lower grade at mid-semester than they might have earned on the theory that it will keep them working at their best. With juniors and seniors the case is reversed. If the students have reached the junior or senior rank, they are supposed to be fairly good students and consequently the instructors do not examine their work as critically as they would the work of freshmen and sophomores where many are expected to fail. This more or less allows the student to float along on his reputation gained in former years.

Another assumption that is closely allied to the above argument, is that familiarity with the students on the part of the instructors results in an increase in grades given without a corresponding increase in achievement. For instance, students come into their future major department for their first courses as freshmen or sophomores. As newcomers they must prove their case; they must prove that they are capable of 'A' or 'B' work before they receive this grade. They establish their reputation; the professors in the department become better acquainted with them as major students. They remember what the students did as freshmen or sophomores and allow the student's reputation to influence unduly their decision in determining grades. As they become more familiar with the students, they are inclined to lower the standard of achievement required without at the same time lowering the grade which is given in recognition of a certain level of achievement.

Some studies have been published where an attempt was made to evaluate the 'acquaintance factor' or the affect of familiarity upon ratings made of the achievements of others. Rugg (2) lays down thorough acquaintance as one of the three essentials for the reliable rating of human character which includes physical qualities, intelligence, leadership, personal qualities and general value. He also states that the judgments of three or four indi-

viduals must be evaluated before an accurate judgment of human character can be obtained. Rugg considers that an accurate judgment has been made if the individual is correctly placed within one of five possible groups. Knight (3) concludes from his study that, " the factor of acquaintance, then, operates to make ratings more lenient, *i.e.,* increases the overrating, and to make ratings less critical and less analytical, *i.e.,* increases the influence of the halo of general estimation. It is in the direction of truth to discount the rating of judges when acquaintance has been long. In a way it is literally true to say of a judge's estimate: His judgment is of doubtful validity *because* he has known his man too long." In the light of other studies it is difficult to take Knight's study at its face value, but even if we do, the acquaintance factor as discussed in his study would not explain this increase in the size of the average grade points for the instructors have not known the students long enough for the overestimation due to friendship to be as great as the rise in grade points. The further fact that the individual student's average grade point for each semester has been determined by the ratings of from three to six instructors would, according to Knight, increase the value of the estimates, and lower the value placed upon the acquaintance factor. Shen (4) reported on a study in which intellectual quickness, intellectual profoundness, memory, impulsiveness, adaptability, persistence, leadership and scholarship were rated. " When we conclude that there is a definite tendency toward overestimation according to friendship, we must remember that the larger part of the errors is due to other unknown factors." These studies indicate that this rise in average grade points cannot be explained on the basis of the acquaintance or friendship factor.

While we have more or less taken these studies of the ' acquaintance factor ' in rating at their face value, we believe that the assumptions upon which they have been made are fallacious. The experimenters have assumed that these traits that have been studied are more or less separate and discrete entities which remain constant from situation to situation. This, however, is not the case. The traits are aspects of a total integrated

situation from which they derive their properties or qualities and as this situation changes these traits change. Of course there is no radical change or variation but there is enough of a change that the estimate of close friends may easily be and probably is a much more expanded and differentiated evaluation than that made by a casual acquaintance. Knight says that friendship "increases the influence of the halo of general estimation". Might it not be more accurate to say that the friendship has allowed the person making the rating not only to expand his conception of what the person rated really is but it has also allowed him more accurately to differentiate and evaluate these factors as a part of this expanded individual which he knows, but which the casual acquaintance does not know. In reality two people rating a third person do not rate objective discrete traits; they rate these traits as aspects or parts of the total situation of which they are a member. The two ratings will naturally vary for the two situations are different. This is especially true if one person is an intimate friend of the person being rated while the other person is only a casual acquaintance. It is because of these conditions that a more adequate description of the individual's general character or personality is obtained from the ratings made by four or five individuals than that obtained from the rating made by one judge.

Another factor that might affect grades is that frequently the upperclassmen are in classes with lowerclassmen. Under these conditions the upperclassmen ordinarily obtain the better grades. Is this difference due to the fact that the juniors and seniors are able to do more work and thus secure better grades because of the quality of work or do they secure better grades because of a greater maturity and hence an ability to do a higher quality of work? Tallman (5) made "A Critical Analysis of Student Persistence at the State University of Iowa" and among other things he found the following: "Although this group remains identical for the four years it does not follow that they are in competition with identically the same group each year. The large increment of students who enter the sophomore, junior and senior classes from other institutions, and the placing of juniors and

seniors in classes which are also open to graduate students changes the relative basis of competition materially. . . . . These data do show that a group of identical students receive higher grades from year to year measured on a grade-point basis than does a group of non-identical students." Thus in a large university the advantages and disadvantages resulting from the upperclassmen competing with underclassmen and with graduate students properly cancel so that the end result will not be influenced one way or the other.

The upperclassmen have their group requirements filled and they can now work in their major departments where they presumably have the greatest interest. If interest and ability are closely correlated as many claim, then the upperclassmen should do better work for they are doing the kind of work they are best qualified to do. Wilson (6) in his study on the "Interests of College Students" says, "There is a moderately high correlation (0.34) between the number of courses taken and the scholarship gained in a given department, indicating that the student does his best work generally in those courses which he chooses more freely." We might very readily admit with Wilson that there is a correlation between the number of courses taken and the scholarship gained but we might well question to what extent this correlation is due to the student's interest and freedom to select courses. Rather, might not this better scholarship be due to the fact that the student is reacting or adjusting himself more and more to the detailed or differentiated aspects of the subject. This process increases the complexity of his responses and produces a higher type of achievement. When a student first enters a class or first studies any subject he reacts only to the grosser aspects of the subject matter just as a person first learning to drive an automobile reacts in a clumsy manner to the grosser aspects of the total situation. As he increases his insight into the mechanism of the automobile or gets a better understanding of the subject matter, he reacts more and more to the detailed or differentiated aspects of the situation. This is the process of acquiring skill or learning and a skilled individual always produces a higher type of achievement than does the unskilled indi-

vidual. In other words the greater achievement is due to the growth or maturation of the student of which interest is an aspect, but not the entire cause as Wilson would have us believe.

The fact that students who rank high on psychological examinations usually rank high in scholastic achievement, suggests the possibility that the two instruments of measurement measure the same or similar phenomena. If we could obtain retests on psychological examinations at various intervals of time comparable to the semester interval, we would have an instrument of measurement which would eliminate many if not all of the questionable features which have arisen in connection with grade points as an instrument of measurement; variation in the instrument of measurement would thus be eliminated. Any changes, therefore, must be changes in the phenomenon under consideration.

Dr. Baldwin (7) retested 1,343 college students at Friends University and the University of Kansas. The mean gain for this group at various intervals of time was as follows:

Time interval between retests	Mean gain
1 day	5.77
4 weeks	6.54
1 year	7.52
1½ years	6.84
2 years	7.48
3 years	8.69

A graphic comparison of the gains on retests with psychological examinations and the increase in the average grade point is presented in Fig. 1. The similarity between the two is indeed striking. This striking similarity indicates that the increase in the size of the average grade point is caused by changes in the quality of the student's work and not by changes in the instruments of measurement.

Dr. Baldwin's comments on his results are found in the following quotation: " Just as we have the general condition in which it is impossible to differentiate between maturation and learning, we have also the more detailed difficulty of differentiating between 'practice', 'inner growth', and 'learning' in the analysis of intelligence scores. It seems to the writer that practice effect increases scores of intelligence tests through its

influence upon the factor of speed of reactions rather than upon the factor of altitude or level or degree of difficulty of the reactions. In response to questioning students retested over a short interval, they explain their gains by the fact that they can 'get the idea' in a very short space of time. This means that more and more the initially insignificant features of the configuration have become the cues of the perceptual pattern and the comparatively few and gross reactions have been supplanted by the more numerous but precise reactions. In the Analogy test, for example, the practiced individual reacts not by floundering among the big ideas of the task, such as the idea of relations 'just as . . . so also', but responds to the more minute details of the particular situation. The individual has learned, he has 'extended his insight into a given situation and has increased the complexity of his reactions'. He apprehends the 'constant but abstract features of a changing stimulus pattern'. Certainly here is evidenced a differentiation of energy patterns of the nervous system and we are justified in classifying the more minute changes, the differences in organization or the development under stimulation of dormant cells, as *maturation*. So instead of the rather labored unconvincing distinction of 'practice effect' and 'maturation' it is much simpler to consider the entire curve a growth process. Certainly the maturation which results from controlled stimulation is just as truly maturation as that 'inner growth' which comes through these factors of stimulation which are beyond control. However, we must recognize that this maturation is of a rather specific type which is accompanied by an insight into a particular situation."

VI. The Problem of Maturation

The work of Carmichael (8) and Bird (9) indicates that the activity or the achievement of the organism is the end-product of a process of maturation or development and not the cause of the development. For instance, in Carmichael's experiment the swimming of the embryos was the end-product of the maturation process and not its cause. The skill with which the chicks in Bird's experiment obtained food was the resultant of a matura-

tion process. Very little if any improvement came as a result of practice. Coghill (10) has shown in his work with Amblystoma that "the normal experience of the animal with reference to the outside world appears to have nothing specifically to do with the determination of the form into which the behavior of the animal is cast. On the other hand, experience has much to do with determining when and to what extent the potentiality of behavior shall rise into action" (p. 87). "From the facts related in his first lecture, it is obvious that there are two processes that are operating simultaneously in the development of behavior. The one is expansion of the total pattern as a perfectly integrated unit; the other is the individuation of partial systems which eventually acquire more or less discreteness. . . . This principle is thoroughly demonstrated by Amblystoma, a typical vertebrate, and there is nothing in our knowledge of behavior to indicate that the principle does not prevail universally in vertebrates, including man" (88–89). The same principles apply to the *human fetus* that were found to operate in the Amblystoma. The first activities are mass or undifferentiated activities while specific or differentiated activities which acquire more or less discreteness appear as the organism maturates. Irwin (11) studied the activities of the human infant during the first ten days of its life when the external stimuli were kept as nearly constant as possible. He found that with a very few exceptions, mass or undifferentiated activity characterized the movements of the infant during this period. The specific or differentiated activities are a later development in the infant's behavior. Gesell (12) with his "method of co-twin control" has also found that the child's development is a process of maturation. These studies all indicate that the maturation of the nervous system correlates very closely with the development of the behavior-pattern of the organism. Or, to put the same thought in other words, the development of the behavior of the organism occurs only as the nervous system maturates and the nervous system maturates only as the behavior-patterns of the organism expand and differentiate. The total organism or the individual is, therefore, the resultant of the maturation process.

Consider what this discussion means to those who are working with college students. The general form of the behavior pattern of the individual is beyond control; little if anything can be done about it. The individual will grow and develop if we make no attempt to assist him; growth is a part of the general behavior-pattern. On the other hand, however, experience or the degree and kind of stimulation to which the individual is subjected "has much to do with determining when and to what extent the potentiality of the behavior shall rise into action". In other words, at the college level stimulation seems to be the most important condition of maturation. When we say most important, however, we do not imply that it is the only condition or that it can be isolated from the other conditions. All of the conditions are a part of an integrated whole and in a way no one can be more important than any or all of the others. But for the purposes of study we shall logically isolate these factors and consider their effect upon maturation. Of course the individual must be in good physical and emotional condition and he must have favorable working conditions such as good lighting, good ventilation, proper heating, *etc.*, but in addition to these conditions it is well known that college work must be adjusted to the level of maturation reached by the individual. This condition and its importance is well illustrated in Gesell's experiment with the twins. The goal toward which the individual is reacting must be definite enough to allow effectual learning; the individual must know the results that he is obtaining in his work; work and rest periods must be properly spaced to avoid irradiation patterns and the individual must use effective methods of study. While all of these conditions are important and have been recognized for some time we believe that *pacing* the student's activities is one of the important conditions that has not been emphasized sufficiently.

Wheeler (13) defines pacing in the following terms: "At present we shall think of pacing as gradually giving the child more and more complex tasks to perform as he grows and matures. The increase in stimulation and in difficulty of problem should not at any time be faster than the child's rate of maturation, otherwise failures to master the tasks at hand are

induced. Too frequent failures lead the child to develop undesirable habits of work and unhealthy emotional attitudes. Once he masters a task of a given difficulty, he should not be presented with another and more difficult task until a recess period has elapsed during which he may *grow* to the more difficult situation. *Theoretically* if the degree of stimulation is adequately controlled, *the child should be able perfectly and easily to solve each new problem the first time it is attacked.* When he must resort to 'trial and error' or to random procedure it is evident that he is not ready for the problem and that the conditions under which he is being forced to learn are not adequately controlled" (p. 115).

Pacing therefore is the process which keeps the student 'on his toes'; the process which keeps the student working at his best and the process which causes him to maturate as rapidly as is consistent with substantial growth. It is the process which avoids the extremes of overstimulation and understimulation but which does allow for moderate stimulation "which if properly controlled leads to a steady normal development of intelligence".

VII. Summary and Conclusions

(1) The average grade point of the group studied increases in size during the eight semesters. This rise in grade points is due to the growth or maturation of the students. The students meet the situations in which they find themselves more and more intelligently which means that they are growing in intelligence. The curve of maturation plotted from the rise in grade points during the eight semesters is almost identical with the curve of maturation obtained by Dr. Baldwin when he retested college students with the National Council Intelligence tests. The groups of college age retested at two state penal institutions, however, lost 6.37 points on the Army Alpha test in a year's time. These facts indicate that at the college level the kind and degree of stimulation very materially affects the maturation of the students.

(2) The average grade point for all of the groups drops during the third semester which is the low point for the eight semesters. This drop is most noticeable among the engineers where the third

semester's work is very much more difficult than is the second semester's work. However, this third semester seems to be a period of social development or maturation which results in a lower achievement as measured by the average grade point. The fact that students do or do not belong to fraternities or sororities does not seem to have any effect upon this slump. From 37 per cent to 50 per cent of the students do not slump but the drop of the remainder is sufficient to cause the curve of the entire group to dip. The standard deviation of the grade points is much greater the sophomore year and especially the third semester than it is any other semester.

(3) The average grade point for the entire group is higher for the spring semester than it is for the fall semester. No doubt a part of this difference is due to the fact that the fall semester has so many interruptions such as football games, Christmas vacation, *etc.,* which the spring semester does not have. But on the other hand, much of this rise is due to the fact that the student has " extended his insight into a given situation and has increased the complexity of his reactions ". This always produces a higher type of achievement which in this case is recognized by the higher average grade points. The studies that have been made by Knight, Rugg, and Shen indicate that neither this rise nor the general rise during the eight semesters can be explained by the instructor's familiarity with the students.

(4) An analysis of the various factors which might affect grades such as the student's familiarity with ' readers ' and instructors, the instructor's acquaintance or friendship with the students, upperclassmen competing with underclassmen, and the student's interest in his major department indicates that none of these factors can explain the increase in the size of the average grade points. The same curve of development occurs when retests with intelligence tests, which are not affected by the above mentioned factors, are used as instruments of measurement.

(5) Intelligence or intelligent behavior is always in the process of development. This development occurs only as the nervous system maturates and the nervous system maturates only as the behavior-pattern of the organism expands and differentiates.

The total organism or the individual is, therefore, the resultant of the maturation process.

(6) This study, no doubt, has raised more questions than it has solved, but it has at least indicated that the changes that occur during the four years of college life are changes which are produced by the growth process and if we wish to understand them more thoroughly we must investigate the factors or conditions which determine the growth process.

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A PSYCHOLOGICAL INVESTIGATION OF THE RELATION OF ILLUMINATION TO AESTHETICS

by

WARREN W. WILCOX AND BEULAH M. MORRISON

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I. INTRODUCTION

It is well known that the illumination under which a picture or work of art is exposed is of importance for aesthetic appreciation. By a proper combination of light, shade, line and surface, the artist creates unity and perspective, form and substance, life and movement. The proper aesthetic feeling-tone is expressed by the plan or design of the composition. The finished work of art is a creation that arouses in the individual a unified type of response that may be described as the aesthetic experience.

Psychological investigation in the field of aesthetics has been confined almost without exception to judging the excellence of the work of art under a constant high level of illumination. Experimenters have generally used as aesthetic test objects a variety of more or less pleasing figures and the observer has indicated his choice by the method of paired comparison, or order of

merit. But these methods are not adequate for investigating the development of the aesthetic response. The appearance of an aesthetic test object is more or less stable, fully developed, and the observer is unable to exercise any imaginative control over its mode of appearance.

The ideal method of investigating the development of the aesthetic experience should obey the following principles: first, the method should permit the aesthetic experience to develop from its inception to its mature form during a single observation; second, free play should be allowed the imagination so that the observer is able to change his mental processes; third, it must not demand as an ideal the analysis of the aesthetic experience into meaningless bits of experience; fourth, the method must provide a means of relatively exact measurement. These criteria of adequacy are approximated in the present study by making a functional analysis of the aesthetic response to varying degrees of illumination of the test object.

The most pleasing appearance of the test object will be called the optimum stage, and this appearance will be contrasted with a lower level, the sub-optimum stage, and with a higher level, the post-optimum stage. The optimum stage was found to be characterized by the appearance of depth, unity, thing character and the completion of the part in relation to the whole. These properties of forms depended in a significant way on the intensity of illumination. The description and psychological significance of these three phases of aesthetic preference form the subject matter of the present paper.

II. Method

1. Apparatus. The purpose of the apparatus devised for this experiment was to regulate and measure the illumination given aesthetic test objects. The apparatus used in the main part of the experiment consisted of two light-boxes enclosing two 150-watt Mazda daylight blue bulbs behind milk-glass diffusion-filters. The intensity of illumination was measured by the size of the opening of two Aubert diaphragms, synchronizing in their operation. The apparatus was found to have a range of 0.1 to 180

apparent foot candles. (The apparent foot candle differs from the actual foot candle value on a plane or surface by the absorption of that surface.) The test object was placed between the two light-boxes and viewed binocularly. A head rest was provided and appropriate screens were used to exclude lateral illumination. The intensity of illumination could be varied rapidly from the lowest to the highest illumination, or in discrete steps. The latter method only was used in the measurement of the light intensities.

In other experiments, the source of illumination was a small lamp which could be moved on a runway, thus regulating the intensity of stimulation.

2. Instructions. The instructions given the observer were necessarily of a general rather than specific nature. We did not know exactly what 'set' to give the observer. We were as ignorant as he of the changes to expect in the aesthetic test object as a result of varying the level of brightness. We did, however, ask the observer to describe the feeling tone connected with the changes in the appearance of the test object. The observer was also asked to give the point of optimum preference, and in some instances, optimum clearness.

Specifically stated, the instructions took the form: "Describe as carefully and exhaustively as possible the changes that take place in the forms before you and, at the same time, give the feeling tone or quality that accompanies these changes. Report the place at which the figure is most pleasing." In other parts of the experiment, the instructions were: "Describe the figures when seen at their maximum clearness."

3. Procedure. The observer was seated before the apparatus in a dark room. Five minutes were allowed for dark adaptation, experience having shown that after this period, the values remained practically constant. The experimenter gave the instructions during the adaptation period, after which he turned on the exposure light. Each observer was given a practice period in which the light intensity was increased rather rapidly. This method allowed the observer to perceive the changes in the appearance of the test object much more readily than by increas-

ing the intensity by discrete steps. The repeated observance of the test object under varying intensities of illumination introduced a degree of differentiation which came from the reciprocal effect of the pleasant on the unpleasant, the simple on the complex, the harmonious on the incongruous.

In the measurement of intensities for aesthetic preference, the illumination was first placed at a low level of brightness. The observer described the appearance of the test object at that intensity. The intensity was then increased by discrete steps until the observer reported some change in the appearance of the test object, at which time, further descriptions were taken. In order to avoid fatigue, observations were limited to half-hour periods. In this way, rather detailed descriptions of the effect of intensity on the appearance of the test object were obtained.

4. Observers. The chief observers were Dr. H. R. DeSilva, Dr. P. C. Squires, Dr. S. H. Bartley, Mr. E. B. Newman, Mr. F. T. Perkins, Mr. M. H. Lewis and the writers. Eight naïve observers also assisted in this experiment. The training of these observers was not limited to any one point of view in psychology.

5. Test Objects. Several types of test objects were employed in this experiment. Twenty-nine geometrical test objects were used—some were devised by the writers and some were taken from figures commonly used in stereoscopic slides. The test objects ranged from very complex figures to simple forms such as ink blots and haphazard arrangements of lines. Certain of the figures were purposely drawn out of proportion. A typical group of the geometrical test objects is shown in Fig. 1. The designs were reproduced on white cardboard which reflected 80 per cent of the illumination while the black components of the figure reflected 5 per cent. The brightness difference, approximately 75 per cent, was a constant factor throughout the experiment. Only the intensity of the illumination was variable.

The pictorial test objects were eleven Perry pictures: Gainsborough's "Blue Boy"; Rembrandt's "Saskia"; Lawrence's "Mrs. Siddons"; Sully's "The Torn Hat"; Vermeer's "View of Delft"; Lawrence's "The Calmady Children"; Kampft's

"Belgian Farm"; Beneker's "Men Are Square"; Millet's "Feeding Her Birds"; Liljefore's "Northern Sunrise"; Murillo's "Children of the Shell"; Raphael's "Madonna of the Chair". Each of these pictures was in color. It was found impossible to measure with any degree of accuracy the reflection coefficient of the different color components of the pictures. The

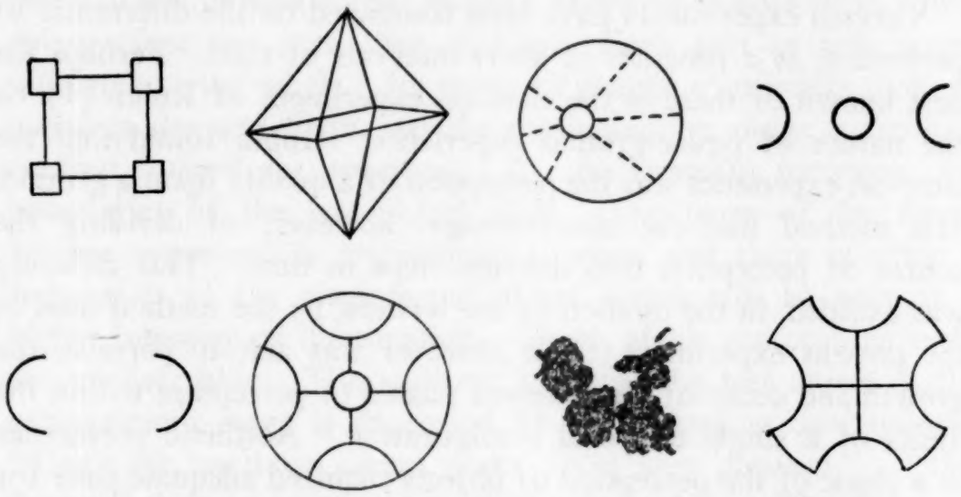

FIG. 1. Samples of Stimulus Cards for the Study of Aesthetics.

brightness measurements, appearing in the quantitative measurements, refer to average brightnesses found by directing a Macbeth Illuminometer at the differently colored portions and averaging the readings of several observations.

The geometrical and pictorial test objects were viewed binocularly at a distance of 28 inches from the eyes of the observer. The geometrical test objects were 1.5 inches in diameter and subtended a visual angle of 3 degrees and 6 seconds; the pictorial test objects were 3 inches in diameter and subtended a visual angle of 6 degrees and 12 seconds. Both types of test objects were centered on white card-board, 5 inches square. The entire test object, therefore, subtended a visual angle of 8 degrees.

Other test objects were made by cutting differently shaped silhouettes from card-board. These were illuminated either from the front or back. This arrangement allowed either the ground or the figure to be entirely light free.

Real objects—statuary, candlesticks and carved vases—were

also used. These objects were observed against light backgrounds or were themselves illuminated and seen against a light-free ground.

III. Aesthetic Preference as a Function of Light Intensity

Various experiments have been conducted on the differentia of perception as a function of short intervals of time. Perhaps the best known of these is the classical experiment of Rubin (1) on the nature of figure-ground experience. Rubin found that the simplest experience was the perception of a quality upon a ground. His method had the disadvantage, however, of dividing the course of perception into discrete steps in time. This difficulty was avoided, in the opinion of the writers, by the method used in the present experiment. The observer was able to perceive the growth and decay of the different phases of perception within the limits of a single temporal configuration. Aesthetic preference as a phase of the perception of objects required adequate time for its full development. For that reason, the method of varying the illumination is to be preferred, as it allows the aesthetic response to develop to its full extent.

Let us consider the development of the different phases of the aesthetic response under the conditions imposed by this experiment. The observer is placed in a dark room before a faintly illuminated test object. He is instructed to describe the appearance of the test object and to indicate the place of optimum preference. If the illumination is progressively increased, the appearance of the test object will go through a regular sequence of changes. At the lowest level of illumination the observer reports a feeling tone of indifference or even, occasionally, of positive unpleasantness. A maximum feeling of pleasantness, of completeness, or of satisfying wholeness is reported at medium light intensities. At extremely high light intensities, an analytical feeling with resulting dissatisfaction and antagonism is reported.

1. The Sub-optimum Stage of Aesthetic Preference. The sub-optimum stage of aesthetic preference lies between the

intensity for the absolute threshold of light and an intensity which falls just below the illumination needed for easy reading. Of the great number of changes in the appearance of objects lying within this range of illumination, we can describe in detail only those concerned primarily with aesthetic preference.

At the absolute threshold for light, both the geometrical and pictorial test objects appear as gray, nebulous extents from which emerge first one part, then another. Each part or area seems unrelated to the whole. Its contours change continually, both in apparent size and shape, *but the predominating shape is circular, tending toward the spherical.* As the intensity increases, the boundaries of the test object shift. The parts of the figure become organized in tridimensional space and there is often a suggestion of the phenomenal object which will be seen at a higher intensity of illumination. Sharp, stable contours as such, are unobservable. The aesthetic value of the test object at the sub-optimum stage is expressed by the following descriptions: "Can't see anything except parts. Not very pleasant." "The figure is just an elaboration of the ground." "The figure is just inferred lines and surfaces." "All I can see is two dots one-half inch apart. No relation between them unless I voluntarily put it there." "I can see various parts and they are not related in any particular way." "The figure is just visible. I can see first one part and then another." "All I can see is circular-like masses of light and shade." "The figure does not have much meaning." "All I can see is a part here and there." "The meaning I weave into the figure is fleeting and fragmentary." "All I can see is a light grayish circular haze—no clear cut forms." "All I can see is just dark roundish blobs in the figure." "Part of the time, I can see an ill-defined square. This characteristic of the figure alternates with a circular appearance."

The silhouette test objects show a characteristic shift of contours. At low intensities the jagged irregular contours appear smooth and assume a relatively circular appearance. The lighted part of the figure seems to float in front of the darker ground. At the light threshold the brighter part of the test object has a filmy, nebulous appearance. As the light intensity increases a

number of forms may appear in the same objectively contoured silhouette. The phenomenal objects thus appearing as a function of intensity, differ in degree of reality. Up to a certain minimum intensity, the reality of the perceptual form is a function of intensity, but with a slightly higher intensity the test object may appear as a lily, a face or an animal. As the illumination approaches the optimum stage of intensity, the organization of the phenomenal object becomes more definite. The test object is then described as some object, a face or an animal. This characteristic of the test object has been called *thing* or *object character* and will be discussed in the next section.

The statuary, candle sticks and carved vases did not differ materially in appearance from the other two types of test objects. *There was the same rounding of contours at low intensities.* The typical form of the test object disappeared at the absolute threshold for light and was replaced by a relatively unorganized group of light and dark areas each of which formed a separate whole. The real, bidimensional properties of these areas were emphasized at the lowest intensities. As the light intensity increased, the parts were seen to form new wholes with their own distinctive properties.

2. *The Optimum Stage of Aesthetic Preference.* The place of optimum aesthetic preference and clearness was measured for each type of test object. Only the absolute values for the geometrical and pictorial test objects are included here. However, as indicated earlier, the optimum intensity for aesthetic preference for the pictorial test objects could not be measured with great accuracy. The results in Table I show that the range of intensity for aesthetic preference was much lower and less variable than the intensity required for maximum clearness. The optimum intensity for aesthetic preference for the geometrical and pictorial test

TABLE I

The relation between the brightness level for aesthetic preference and for maximum clearness in apparent foot candles

	Mean	Mean variation	Number of observations
Aesthetic preference	2.4	1.7	115
Maximum clearness	87.5	8.0	456

objects was found to be 2.4 apparent foot candles. The intensity required for maximum clearness of the same test objects was found to be 87.5 apparent foot candles. While these results are probably only relative, they indicate that aesthetic preference is not entirely a matter of clearness. Indeed, the reports of the observers bear out the conclusion that the two types of response are quite different.

At the optimum stage of aesthetic preference the appearance of the test objects is characterized by such words as "like", "interesting", "best", "a good structure", "richer", and "pleasing". The parts of the test object are seen as members of wholes and new properties emerge. The most common of the emergent properties are the appearance of depth, or organization in tridimensional space, thing character, and the completion of the part in relation to the whole. Accordingly, the figure is described as having a particular organization, form, plan or design. The details of the figure as they emerge are clearly members of this form or design. The differentiation of color at the optimum stage also plays a part in the organization of the aesthetic wholes.

For the most part the observer did not mention one aspect of the figure as affecting his choice. He judged the place of optimum preference and described the appearance of the figure as a whole. The description of the test objects approximates the property of the real objects: "The figure has bulk. It is a good substantial figure." "I find myself making a wheel out of the entire figural field." "The lines are warmer and blacker than before and seem to be part of a figure rather than just lines." "The internal hexagon stands out. The other lines form a general ring around the hexagon. The lines as I see them are sharp, clear-cut, but do not appear to be such but as parts of a thing." "The figure looks like a rubber ring. The two sides represent the two sides or extremities of the thing. The middle part curves toward me." "Now I can get a baseball out of the figure. I see the figure as a whole." "The top figure looked like an Indian head." "As I watch the black masses take on the characteristics of faces." "There seems more solidity to the face and the figure appears more life-like than before." "The

clouds seem like clouds and the water looks like water." "The picture is a little distant but has the character of reality." "The light helped her face. The face rounded out. She is more life-like than before and looks healthier." "The figure of the man looks real, dynamic."

A significant property of thing character is a subjective shading of completion of the test object in the direction of a closer or more homogeneous unit. Certain figures lend themselves more readily to this completion phenomenon than others. It has been known for a long time, for instance, that semi-circles and circles may appear darker in the center. A great reduction or increase in the intensity of illumination has the effect of rendering the completion phenomenon less apparent. The completion phenomenon gives the figure stability and the quality of reality. It is typically described as follows: "The figure seems darker in the center than before." "The inside of the figure is darker than the surrounding area." "The inside of the bucket, that I see, is much deeper in shade than the outside." "I like the figure best when the outside is a little lighter than the inside." "Two arcs stand out. They have thickness and tend to complete themselves." "The goodness of this figure depends upon tied imagery. There is closure of a sort. It is fairly pleasant."

The subjective shading or completion of the figure is not confined wholly to light and shade effects but sometimes appears as a coloration of the test object: "There is a gradual shading in the figure from the center to the outside. Around the outer edge I see an orange circle. "The lines pair off markedly. It looks almost like some color scheme. The colors are half way between pink and purple." "The figure appears like a moon. It is rather darker in the upper part than the lower." "I see a crooked line that is crescent-shaped. It tends to complete itself and make an oval. The oval is darker than the surroundings, particularly the inner part."

Although the observer described the test object as a whole and did not mention one aspect as affecting his choice we find this rule is not invariable. Thing character or its descriptive form was most often mentioned as affecting choice. Only those

observers who were more sophisticated psychologically than the others used the name, " thing character ". Figures appearing in relief and seen as real objects are preferred to bi-dimensional non-object-like appearances. The following descriptions all show the influence of thing character on the observer's choice: "As the light increases, the figural field changes into thing character. The greatest appreciation comes when the real character of the figure changes into thing character." " The thing character of the bowl determines my choice." " I do not know how to describe the change (from a lower illumination) except that the richness of the lines makes me prefer them. There is a certain breadth and thickness to the lines."

The appearance of phenomenal depth is also given as affecting the preference for the figure. The function of phenomenal depth is the organization of the parts of the figure. Figures drawn out of proportion and unsymmetrical may appear as balanced by the retraction or extension of parts of the figure. The depth effect itself is described as pleasant. This general point is shown in the following reports: " The appearance of depth increases my preference for the figure." " I like the figure there the best. There is a sort of interlocking depth effect that is pleasant." " When I get a depth effect the feeling is rather pleasant." " I can see depth in the picture. I like the picture a little better than I did before."

3. The Post-optimum Stage of Aesthetic Preference. The post-optimum or clearness stage is characterized by disintegration of the figure to simpler forms. The characteristic properties of the optimum stage disappear and different properties take their place. The thing character of the test object changes to a real, superficial, bidimensional extent. The observer typically describes the figure as relatively flat, uninteresting, as having little unity, or subjective completion. The defects in the figure are evident. Drawings appear as drawings; pictures appear only as pictures. It is as if the observer saw the test object without illusion. Parts of the drawing may appear out of place or unrelated to the rest of the figure. The pictorial test objects seem over-exposed. The intense light distorts the contours of the

pictures and destroys the harmony of color and form in the picture. The observer finds voluntary control of the figure difficult. Spontaneous analysis of the figure is more evident at the post-optimum stage than at any other.

The words used to describe the feeling tone characteristic of the appearance of the test object at the post-optimum stage are the opposite of those used at the optimum stage: "Don't like it there." "Uninteresting." "Not so good." "Indifferent." "Poor."

Lack of unity and disintegration of the geometrical test objects are shown by the following reports: "I can see a white indefinite figure. The background is black and there are hard dark spots on the figure." "It appears as fragments rather than as a whole. There are changes in structure that cause the figure to fall to pieces." "The figure tends to break up into pieces." "The figure breaks up into parts which do not 'fuse' without an effort."

Lack of unity and disintegration of the pictorial test objects at high intensities is shown by these reports: "I see only blotches. The colors are unnatural and in the same plane. Everything but the face of the boy is blotched." "I can see all the imperfections in the picture." "Her garments look stiff and hard. I can see wrinkles in her neck. The shadows come out of the clothes making them appear hard and stiff, unreal." "There is discord in the balance of the shadows." "The intense illumination makes the details stand out too clearly." "Just a big splash of red. I can't tell what the picture is."

A too high illumination changes the natural sweetness of a pictured face to a "hard, cold, expression". The eyes may become "hard and piercing; the expression hard and blasé". Imperfections in the reproduction are too evident. The intense illumination accentuates the light parts of the picture at the expense of the dark. As a result the whites of the eyes may appear too evident or a face too large and distorted. Children's faces appear "hard and pinched" or "stiff and lifeless". The intense illumination sometimes makes an otherwise pleasant face

look "mean" "untrustworthy", "the features gross and distrustful".

Thus characteristic features of the optimum stage disappear. Although this change is easier to determine in the relatively simple geometrical test objects than in the pictured reproduction it is evident that the same process is occurring in both types of test objects. The most evident change in the appearance of the test object under a too intense illumination is a loss of object or thing character and a lessened depth effect. Reality for most pictures and geometrical designs depends on organization in tridimensional space. If the depth effect disappears under a too intense illumination, object or thing character disintegrates. The test object is then usually described as an artificial drawing or picture.

In the geometrical test objects loss of thing character and tridimensionality is shown by the following reports: "Not much depth or thing character except as a mere drawing." "The lines of the figure do not stand out and appear as lines instead of bounding areas." "The figure becomes lines again. It is just a mere drawing. Too much light." "The figure gradually fades into ink blots. The associations disappear and the figure becomes flat." "The figure is becoming too bright. The heads disappear and all I see is an ink blot." "The figure is gradually becoming just a plain geometrical figure without much depth or contour."

In the pictorial test objects, the observer describes the loss of object character and depth by describing the picture as a mere flat reproduction: "Boy's clothes do not look like clothes. No depth effect at all." "Here this thing is getting toward the picture stage again. It is flat compared with the former illumination." "The face is becoming flat and uninteresting." "The picture is too bright to be real. It looks like a picture instead of a human being." "The picture appears stiff and lifeless. It is flat and uninteresting." "The picture has lost its dynamic quality."

4. *Apparent Movement in the Test Object.* Apparent movement in the objectively stationary test object has great impor-

tance for the development of aesthetic totalities. The apparent movement is, however, not restricted to any particular stage of aesthetic preference. At the absolute threshold, the movement is toward closed contours, rounded boundaries, gross differentiations of light and shade and relatively simple depth effects. The perceptual field is in a state of continual change; parts expand or shrink in apparent size; contours project in space and then retreat. The new forms come into being movingly, by sudden jerks; they are alive, vital. It is only with increasing intensity that the simplest symmetrical figures are modified in favor of the demands of the stimulus. The growth and disintegration of the perceptional forms progresses by means of these apparent movements. The intermediate forms have a quality of directionality, of non-finality; they point beyond to the most symmetrical figures. Some forms are unbalanced; they demand correction, balance, stability. These forms merge as by internal necessity to new creations which in turn are transitive phases of more highly structured symmetrical forms. Other forms are over-symmetrical (artistically) and lack the complexity of organization demanded in the most symmetrical figure. Increasing intensity changes their internal organization. New qualities emerge or parts of the old object move in space. The direction of the movement is toward greater balance and symmetry. With the highest and most blinding intensities the organization of the optimum stage of aesthetic preference breaks down. Simpler forms predominate in perception. The contours of the white parts of the figures expand; the dark components contract.

A common type of apparent movement was the orientation or localization of particular lines or parts of the figure in tridimensional space. The observer was often conscious of attempting to 'right' an unbalanced figure by changes of perspective. Descriptions of apparent movement appear in the following reports: "The points of the pyramid shift back and forth but keep the double pyramid effect." "The figure looks closer and then farther away." "As the light increased the figure moved toward me. I could look into the extended part. It then made a better balanced figure. As the light increased still more the extended

part of the figure moved back and the figure lost its depth effect." "A depth effect appears. The lines come out from the ground. As I watch, certain segments of the figure stand out more than the others." "As the light increases I get fluctuations of perspective. The illumination brings the figure toward me."

Another type of apparent movement is the bending or weaving of parts of the figure. Parallel lines pair off in series; groups of dots arrange themselves in a pattern. We find this apparent movement described as follows: "Starting there, the lines pair off markedly. The lines look wavy and move back and forth." "The dots jumped into a series of rows as the illumination increased."

At times the figure definitely suggests rotation: "The figure seems to move in a circular direction." "The figure suggests rotation. It seems to be a wheel with a dark spot for the hub."

Sometimes the observer voluntarily changed the position of the members of the test object to a more symmetrical, balanced whole. Voluntary control of the test object came at the optimal stage of aesthetic preference. Of several forms which might persist in perception the observer was directed in his choice by the affective value of the total experience. The voluntary control of the aesthetic appearance of the test object is shown by the following reports: "I voluntarily change the figure to a star. I like it best there. The star was built on the wreck of the old figure. The star figure bends the lines. When I hold the star in perception the undirected lines tend to drop out." "I find myself making a wheel out of the entire figural field. The ends of the arm are gradually becoming round." "At the optimum stage I was conscious of trying to make the center part go back to a point in the cube adjacent to the upper part. It is a good substantial solid there." "The position of the little dot in the center is uncertain. I am conscious of trying to put the dot somewhere. I finally find a place for it. Before the dot was in the road." "This is the first time I have seen the figure that way. I can see it as a pyramid, a hexagon or any other way I wish. A pyramid figure finally persists in perception. I like it best that way." "At one time I see a circle, a wheel, another figure. I

should prefer to see a cogwheel. As I watch, the cogwheel becomes more substantial. The windmill figure which I can just make out now seems a little out of balance." "The figure comes out with an extreme depth effect. I feel as if I can reach out and do anything with the figure I wish. The ability to do something with the figure increased my pleasure in its appearance."

IV. Theoretical Interpretation

We may trace the course of a dynamic principle in the nature of the dependence of aesthetic preference on the intensity of stimulation. The preference for balanced symmetrical forms over asymmetrical ones in experiments on memory (2), visual threshold patterns (3), the completion phenomenon found in after images (4), and the roundness of cutaneous spots (5, p. 438) suggests that the law of least action is fundamental to all of these phenomena. In terms of least action a dynamic fluid distribution of energy "exists in the form of systems or configurations of stresses, and if one system affects another, the changes that take place are changes of the total system" (5, p. 78). Balance, symmetry and proportion are laws of the distribution of energy whether found in aesthetics or purely physical systems. The most symmetrical form requires the least energy for its preservation. Principles of organization are inherent in aesthetic totalities as well as in our most common-place perceptions. The change in perception that follows variation in intensity of stimulation follows the law of least action.

If it is true that perceptual experiences follow a dynamic principle, it is evident that the nature of the experience should approach the ideal properties of dynamic equilibrium when the perception is freed of the too insistent demands of the stimulus. This condition prevails at the beginning of the sub-optimum stage of aesthetic preference. Under a just sufficient intensity of stimulation for a perceptual response, the nature of the experience is molded in accordance with the dynamic principle of least action. The perceptual object approaches the form of the circle, the simplest symmetrical figure. There is a minimum of expenditure of energy to preserve the figure in perception. Indeed, the

circle is the only figure which can exist under the conditions. The perceptual field is in a state of unstable equilibrium. Contours shift, there are great changes in apparent size of the threshold pattern.

It is only with increasing intensity of stimulation that the simplest symmetrical figures first seen are modified in favor of the demands of the stimulus-pattern. The growth of the perception to the final or end-form of the stimulus is not the progressive unfolding of a replica of the stimulus. The development of perception comes from the emergence of new properties, the appearance of old parts of the stimulus-pattern in new and distinctive forms, and the organization of the test object in bi- and tri-dimensional space. Typically there is the emergence of not one but several forms in the stimulus-pattern prior to the development of the optimum configuration. Up to a certain optimum intensity, the amount of energy expended by the observer is in inverse ratio to the intensity of stimulation. The mere act of seeing under unfavorable conditions for clear perception of the forms is very fatiguing. There are certain difficulties in organization at the sub-optimum stage which reflect the adverse conditions for perception.

The optimum configuration is maintained with a minimum of expenditure of energy on the part of the observer. Symmetry and balance are the properties of mental and physical totalities. The object actually favored in perception is the most symmetrical and balanced under the conditions of stimulation. But objects differ in the complexity of their organization. The more highly organized an aesthetic object the more energy the organism has for new and striking adjustments. It is for this reason that some objects by their vital organization fill the whole of conscious experience.

If the constellation of the stimuli runs counter to the demands of balance, proportion and symmetry, the observer is aware of emotional tensions, of surges of unpleasantness. He is painfully aware of trying to right an unpleasant figure, to mold the form in accordance with a dynamic principle of equilibrium. Under too high illuminations, the test object appears unbalanced,

unsymmetrical. The observer is fatigued easily. The demands of the stimulus are too insistent. The test object loses wholeness, unity, balance, thing character. Parts appear unrelated. A vast amount of energy is expended to maintain the unity of the parts of the test object. The course of the perception has been forced to run counter to the demands of an energy system in equilibrium.

V. Summary and Conclusion

1. Experiments are described which indicate that the nature of the aesthetic experience varies with intensity of illumination.

2. The optimum level of intensity under the conditions of these experiments was found to be 2.3 apparent foot candles. The preference for the test object at this intensity was correlated with certain phenomenal properties of the test object. Below and above the optimum intensity the test object was unpleasant.

3. At the sub-optimum intensity the appearance of the test object favors over-symmetrical, simple forms. Circular forms predominate; the tendency is toward closed, rounded contours and a minimum of differentiation. The observer finds difficulty in maintaining adequate perception of the threshold stimulus.

4. The optimum intensity is correlated with optimum organization in the form of the test object. The most symmetrical figure has the properties of thing character, unity, and organization in space. The optimum intensity allows the observer to maintain the adequate form of the stimulus in perception with a minimum expenditure of energy and a maximum of organization.

5. The post-optimum intensity is characterized by the disintegration of the test object to less symmetrical, simpler forms.

6. Several types of apparent movement were observed which have great importance for the development of aesthetic totalities. This movement was found to favor the greatest possible symmetry under the conditions of observation.

7. The law of least action has been applied to the aesthetic experience. In terms of least action the figure persisting in perception requires less expenditure of energy on the part of the observer when it has the greatest possibly symmetry under the

conditions. The optimum intensity favors the highest organization in the test object with a minimum expenditure of energy.

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